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Produced by the NASA Center for Aerospace Information (CASI)

Final Report

# OBJECTIVE TECHNIQUES
# FOR
# PSYCHOLOGICAL ASSESSMENT
# PHASE II

74-10681

August 30, 1974

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lyndon B. Johnson Manned Spacecraft Center
Houston, Texas

NAS 9-12771

**GARRETT**

AIRESEARCH MANUFACTURING COMPANY
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# FOREWORD

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# SECTION 1

## INTRODUCTION

This document presents the results of an initial experiment in a research program designed to develop objective techniques for psychological assessment of individuals and groups participating in long-duration space flights. Specifically, this report describes the rationale for utilizing measures of attention as an objective assessment technique; previous research of various performance and psychophysiological methods of measuring attention are discussed; the experimental design, apparatus, and results are described; and conclusions and recommendations are presented.

## Background

Individual and group behavioral problems that can be anticipated during long-duration space flight have been reviewed by Fedderson and Kanas (1971). These authors conclude that psychiatric and sociological problems should be solved prior to missions of long duration. To meet these objectives, appropriate psychological assessment techniques must be developed for the purposes of (1) assessment of individual and group status during flight (to allow for psychiatric intervention when necessary), and (2) selection of crew members.

Both selection and psychological assessment present many difficult theoretical and methodological problems. The foremost obstacle to direct assessment is the development of measures that possess construct validity in relation to individual, group, and mission functioning. Measures selected must be defined in terms referring to processes that covary with functional effectiveness. One significant consideration is that of value context, i.e., the relative importance placed on various individual, group, and mission objectives. Thus, research and development should progress along lines specific to the explicit and implicit values inherent in personal, group, and mission objectives. Choosing concepts that refer to processes broad enough to be generally useful, while retaining enough functional specificity to avoid vagueness and allow direct assessment, is of paramount importance.

These considerations call for the assessment of individual processes that affect functioning at many levels of activity and, at any given level, affect a broad range of behavior.

Continuous or repeated psychological assessment engenders problems not encountered in the current research in assessment of intelligence, personality, and social variables. The many equivalent forms of a particular assessment instrument used for repeated measures would be most difficult if not impossible to construct. Moreover, repeated pencil-and-paper tests or repeated projective tests would be of little diagnostic value without prior test standardization under conditions of space flight.

The physical conditions of prolonged space missions preclude certain kinds of testing, and mission task requirements preclude the use of other forms of testing. Much of the remaining assessment methodology is not relevant to the current objectives. The development of tests and procedures that circumvent the special problems and constraints encountered and provide sensitive, reliable assessment data relevant to functioning in many different modes and tasks requires the selection of dynamic processes that are basic to effective behavior in general.

Traditional personality psychodynamics and trait theories are based on the assumption that relatively stable personality, constructs, or traits exist which describe and/or give rise to stereotypical behavior. Given that the dimensions of personality are basic processes, each of these approaches contends that a variety of responses ultimately reveal a person's underlying personality structure when the behavior is properly interpreted. The major determinants of human behavior in the psychodynamic view are unconscious and irrational and are driven by persistent demands from within.

Investigations seeking validation of these assumptions, crucial for assessment of the type being considered here, have generally failed to provide convincing evidence that people do behave consistently across many diverse situations (Mischel, 1968). Such evidence would be essential to sustain the belief in the broad personality dispositions which theories posit. The highest correlations across situations that demonstrate stability over time are associated with cognitive and intellectual functioning. Even here, researchers are quick to point out the relative independence between academic and non-academic, and artistic, scientific, and social achievement (Holland and Richards, 1965). Also, it would be necessary to show that inferences about an individual's traits and states permit important predictions about his behavior. A massive amount of data (cf. Mischel, 1968) suggests that this is not the case.

Assessment, prediction, and modification of behavior would be relatively easy if behavior consisted of stable, highly generalized response patterns that occurred regularly in relation to many diverse stimulus conditions. However, what people do in all situations and on all tests can be affected and modified substantially by many stimulus and environmental manipulations. Thus, only measures obtained under the conditions of interest hold validity with reference to detection and prediction.

A focus on behavior change, rather than upon hypothesized stable traits or states, leads to emphasis in assessment that is quite different rather than traditional. In behavior analysis, the emphasis is on what a person does in situations rather than on inferences about what global attribute he has. What people do, of course, includes much more than motor acts. Humans do exceedingly complex and varied things. Among many other activities, they create and destroy, and they think and theorize. All these and other tasks depend on certain basic processes of attention and perception that may be considered superordinate behavior. Disruption and malfunctions of attention and perception may be considered to have a rather broad, deleterious effect upon goal-oriented behavior occurring in the course of many different activities.

Standardized diagnostic items and procedures in use today have undergone a process of development that is by no means culture-, habitat-, or stimulus-free. Even conventional performance tests that measure basic capabilities necessary to any normal functioning (such as attention focus, span, and flexibility) are relatively culture-bound and are task-specific in nature. Taken out of the ongoing flow of routine crew activities solely and overtly for the purpose of assessment, such measuring devices perturb the very systems they are designed to assess. For these reasons and others such as problems of standarization and administration, availability of suitable forms and methods, and feasibility of obtaining repeated measures relatively unconfounded by repetition, currently available conventional diagnostic tests appear inappropriate.

To provide the necessary sensitivity, minimum of interference with ongoing function, and minimum self-consciousness or preoccupation with performance, it was decided that both performance and psychophysiological monitoring be investigated as a potential source of objective data. Used in conjunction with computer-assisted cooperative performance indices, performance indices may be established when the task (from which performance and psychophysiological indices of attentional states are obtained) is a regularly performed, cooperative duty of two or more crew members. It is hypothesized that under actual working conditions, individual, group, environmental, and performance constraints simultaneously affect the attentional behavior and correlated measures obtained from crew members. Performance and psychophysiological variables gathered under actual working conditions are most likely to be indicative of those aspects of psychosocial well-being which have relevance for functional effectiveness and which are most likely to have predictive value for subsequent behavior over the course of the space mission.

The machanism of attention involves a screening or selection of inputs at all stages from the peripheral receptors to the final brain analyzers themselves. This selection process is a subtle one and involves a continuum of attention varying from focal awareness to unconscious levels of attentive activity. Though the mechanisms are unclear, it is apparent that attention may simultaneously possess both wide range and sharpness of focus (Meldman, 1970). In the larger sense, disease (meaning to suffer or to be out of ease and comfort) implies the recognition of stimuli arising from focal pathologic conditions. This recognition by the subject requires attention, and consequently alters attentional equilibrium.

For disease to affect the person as a unit, it must alter attentive activity. Thus, attentional activity may become the convenient barometer of well-being. That disease processes affect the rate and distribution of attention is a matter of everyday clinical experience (Meldman, 1970). Fevenczi (1950) observed that disease is regularly associated with a withdrawal of attention from exteroception accompanied by an increased distribution of attention to the patient's body and, possibly, diseased organ. He called this effect of sickness on behavior the pathoneurosis.

Focal stimulation, irritation, or pain has the effect of capturing attention more or less completely, depending upon the attentional unit and equilibrium of the sytem. The potent arousing quality of nociceptive stimulation makes it logical that it should bear a close relationship to the ascending reticular system (Magoon, 1963). Pain increases arousal level and directs the focusing of attention to its origin. This is associated with a decreased distribution of attention into exteroception. In this instance, a focal pathologic lesion acts as an etiologic agent in causing an alteration in the attentional functioning and equilibrium of the subject.

The external and internal stimuli together make up the forces that affect the attentional functioning. The combined effects of focal and nonspecific responses can be observed in alterations in attention. Whether produced by normal or pathogenic sources, these alterations in attention produce the signs and symptoms that are associated with the clinical picture of illness (Meldman, 1970).

Attention is a primary physiological integrative process, and each organism has a limited capacity of available attention. Since attentional capacity of each person is finite, it follows that imbalances of attention will arise through the selective investment of too much attention into any one of the several subsystems, and that this will further be accompanied by the removal of attention from other subsystems. Thus, the latter are deprived of those integrative properties of attention that serve the formation of complex behavioral sequences. One's ability to invest attention with ease and rapidity, without directional limit or obstacle, and to withdraw attention effortlessly and rapidly are capacities that are hypothesized to be synonomous with well-being.

Attention equilibrium and flexibility of attentional investment depend on the development of the following capabilities: (1) an ability to grasp and hold stationary the field of interest or object of attention, and (2) an ability to release hold of the attentional objects of fields and of the subject-object distinction itself. Without both the ability to fully grasp and the ability to completely let go of attentional objects, optimally effective functioning is impossible. Thus, the initial research into methods of psychological assessment was addressed to attentional abilities.

REVIEW OF RECENT LITERATURE

Reviews of the broad and varied subject of attentional behavior can be found in Koster (1969), Sanders (1970), and Mackworth (1970); in addition, Moray (1969) proposed six different meanings of attention as used in psychological research. Posner and Boies (1971), however, provide three general concepts or categories under which most research (as well as Moray's meanings) can be categorized. These are listed below.

Alertness, or Arousal--A varying state of readiness to detect stimuli in repetitive, boring, or low-stimulus frequency tasks (such as vigilance tasks). The term also relates to level of sensitivity to stimuli during periods of preparation for receiving stimulation. Both performance measures (e.g., Mackworth, 1970) and physiological measures (e.g., Näätänen, 1970) of alertness provide rationale for including alertness as a component of attention.

Selective Attention--The ability to select one kind of information from another or to select one source of information from other sources. Studies of selective attention may involve sensory modalities, location of signals, selection of responses, content of the information in the stimulus array, or internal templates, models, and memories of past events.

Limited Central Processing Capability--The difficulty in handling two tasks simultaneously; the delay of signals that arrive during reaction time.

For the purpose of this review, emphasis will be placed on the first two topics above and an additional category, Psychophysiological Factors, will be added. This latter section is presented separately because the nature of certain dependent variables, and their utilization as indicative of major modes of responding on an organismic level, has received great emphasis and aroused considerable controversy.

## ALERTNESS, ISOLATION, AND CLINICAL FACTORS

Fedderson and Kanas (1971) reviewed the stresses of long-duration space flight and argued for improved personnel selection techniques and better understanding of these stresses so that intervention strategies might be developed. Memford (1970) argued for utilization of responses to stress as indexes for selection of personnel and presented data from psychological, physiological, and chemical tests.

Zubek (1970), reporting on behavioral and electroencephalographic changes in individuals and groups of men during 14 days in isolation, emphasized the changes in their perceptual processes.

Another recent study on isolation by Serafetinides (1971) also found an ever-present progressive reduction of cortical activity in cases of sensory deprivation. It appears that this perennially consistent alteration in the EEG could be accepted as prima facie evidence of sensory deprivation.

Evidence that the effects of varied levels of sensory input represent a two-edged sword was obtained by Zuckerman et al. (1970). Utilizing subjects in confinement, they produced environments designed to provide high, normal, and low levels of arousal by manipulation of sensory variety in the environment. They found that anxiety and adrenocortical responses were elevated in both the high arousal and low arousal situations as compared with the control situation. Of the two extreme conditions, subjects preferred the high arousal situation to the low arousal one, which was associated with depression. From this and other work (such as that of Frankenhauser et al.), some approximation of the optimum level of arousal that should be the design objective for space stations and other long-duration manned systems can be obtained.

Shapiro et al. (1970) observed the effects of sensory reduction in organs and systems not usually monitored in this type of research. They found that reduction of auditory and vestibular inputs resulted in a marked inhibition of gastric secretion.

In trying to understand the relationship of monotony to psychophysiological responses, Coffman and Kimmel (1971) studied a situation in which the occurrence of a brief light flash in the dark would be contingent upon the occurrence of a galvanic skin response (GSR). They found that there was instrumental conditioning of the GSR under these conditions. Consequently, they argued that the occurrence of an orienting response may have a reinforcing effect. Orienting responses are discussed subsequently.

Bohlin (1971) studied the effect of monotonous stimulation on the rate of sleep onset and habituation of the orienting response. He found that monotonous stimulation put his subjects to sleep more quickly than no stimulation. He also found that the rate of habitation of the orienting response tracked the rate of sleep onset. For a comparison between boring stimulation and boring responses, London, H., et al. (1972) studied change in autonomic arousal during performance of boring tasks. They found higher heart rates with very boring tasks and suggested a curvilinear relationship between information rate and antonomic arousal. It is their suggestion that both boring, highly redundant information and low redundancy, rapidly changing situations will result in higher heart rates than will moderate levels of information processing.

Frankenhauser, et al. (1971), in studying psychophysiological reactions to understimulation and overstimulation, found that these two conditions increased the rate of adrenaline and nonadrenaline production as compared with controls at moderate levels of stimulation. They also found that subjects

who produced more adrenaline performed better in the understimulation condition, while subjects with less adrenaline production performed better in the over-stimulation condition. The same observation was made with heart rate as the dependent variable. They interpret their data as supporting a curvilinear relationship between level of arousal and performance, with performance being optimal at moderate levels of arousal. Averill, J.R. et al. (1972), in a study on complex emotional study, observed that when subjects were shown an isolated accident scene out of context they invariably responded with slowing heart rates; however, if the accident scene were shown within the context of an action film, the opposite response, heart rate acceleration, was observed.

Orlando et al. (1973) found no experimental support for the prediction from the arousal theory that environmental variation enhances vigilant support by providing the maintenance of a high state of arousal. Their use of short (90 min) sessions poses a major reservation on the general applicability of their data.

Lekert et al. (1970), investigating sensory deprivation, suggest that deprivation produces a need for stimulation that is satisfied by attending.

Related observations by Berlyne (1966) indicate that the extent to which a stimulus increases arousal, corresponds to its novelty and depends on the subject's initial arousal level. He also suggests that the reward value of a stimulus is a curvilenear function of the degree to which the stimulus causes arousal.

Gale et al. (1972) reported that good performers in vigilance tasks are lower aroused than poor performers.

May and Johnson (1973) reported that unpleasant internal stimulation leads to increased autonomic reaction, especially to HR increases.

Klormer (2974) demonstrated that the HR response to fear-inducing material habituated rapidly.

Rathbart and Mellinger (1972) studied attention and responsivity to remote dangers and found substantial individual differences in their population, which they characterized as fear repressors and sensitizers.

In a study along similar lines, Rice and Greenfield (1969), studying the psychophysiological correlates of "LaBelle Indifference", found that patients who remained calm in the face of frightening and disabling impairment showed greater physiological arousal than did control subjects. They concluded that psychological defense does not prevent arousal of covert physiological corre-lates of emotion.

Schmolling and Lopidus (1972), studying performance in schizophrenics, found that schizophrenics have an elevated base level of physiological param-eters. Consequently, under stressful stumulation (in accord with the law of initial values) little increase is seen above baseline values for physiological measure. They characterize these subjects as being hypervigilant, impaired in attending, and showing difficulty in shifting the response set.

Cohen and Douglas (1972) reported that hyperactive children have slower RT's than normals, were more variable in the RT, and that the RT was not helped by an alerting signal.

Lefcourt and Siegel (1970) report that subjects who are more engaged in fantasy (more "M" response on the Rorschach) have slower reaction time.

Little recent research has been conducted on shifts of attention or perception. Mackintosh and Little (1969), using pigeons, have shown that strengthening of attention to a single relevant dimension increases the rate of response reversal. Schell (1971), in experiments with children strongly resembling "learning set" experiments, also has shown that learning to attend to one stimulus dimension at a time improves the shift of attention from one stimulus dimension to another.

The rate of reversal of the Necker cube illusion was investigated by Roland (1970). He found that stress, in the forms of cold pressor stimulation, increased the rate of reversal of the illusion. Heart rate also was correlated with the rate of reversal of the illusion.

## SELECTIVE ATTENTION AND PERFORMANCE

Typical studies within this category on sensing modality have been made on visual and auditory signals processing by Mackintosh and Little (1969) using pigeons, and by Webster and Haslerud (1964) using humans. Wachtel (1967) presented a survey of evidence suggesting that attention is like a beam of light focused more or less sharply on particular sources of incoming data. He suggested that a distinction can be drawn between the narrowness of focusing at any time and the extent to which the beam ranges over the field of attentional opportunities. He proposed that characteristic tendencies in these two respects can be regarded as facets of personality varying between types of individuals. For example, highly anxious people can be thought of as tending to have a narrow beam that roams widely over the field so that their attention skips rapidly from item to item, but is intensely directed to any item on which it is actually resting. Welford (1970) commented that "...selection seems commonly to be made in terms of attitudes and hypotheses brought to a present situation from past experience--we perceive what we expect to occur or along the lines of what is familiar. It seams clear, therefore, that selection must often be a high-grade process, concerned with data which have already been processed to a substantial extent by the mechanisms of perception. This may well be true even when selection appears to be made in terms of simple sensory quantities."

Classic data in support of this last statement by Welford was .reported by Cabanac (1971) in a study of alliesthesia. In this study Cabanac demonstrated the effect of changing physiological states on the qualities of incoming stimuli. In his studies temperatures and gustatory and olfactory stimuli judged as pleasant under one set of physiological conditions were judged as unpleasant under another. For example, a pleasant tasting liquid became too sweet for hours following ingestion of glucose.

A wide variety of experimental studies has shown that perceptual selection is a task involving some mental activity by the observer, and the more precise that selection must be, the longer it takes or the higher the risk of error.

Baddeley (1972) suggests that it is plausible to assume that an increase in arousal will focus the subject's attention more and more narrowly on that aspect of the situation that is of greatest immediate importance to him. If this happens to be the task he is required to perform, then his efficiency will be increased; if not, his performance will deteriorate until he abandons the task.

Fortunately, however, response to a dangerous environment may be much more adaptive than this. Work by Epstein and Fenz (1965) suggests that the experienced parachutist learns to inhibit anxiety since it tends to disrupt performance. They suggest that both the fear and the inhibition focus on the jump but generalize temporally both to prior and later aspects of the jumping situation, and to other stimuli associated more or less closely with jumping. If one assumes the generalization gradient associated with the inhibition of fear to be steeper than that associated with fear itself, then the point of maximum emotional response will tend to be displaced away from the danger stimulus; the greater the degree of inhibition, the farther away will be the displacement.

It seems then that subjects who are repeatedly exposed to a dangerous situation can in some way learn to inhibit their anxiety and displace it away from the point of maximum danger.

Considerable literature already exists on the effects of physiological arousal on performance, much of which suggests that they are related by a function resembling an inverted U; that is, as arousal increases, performance improves up to a maximum beyond which further increments in level of arousal lead to poorer and poorer performance (Hebb, 1955; Malmo, 1959). A good deal of experimental data can be accounted for in terms of the inverted-U function. One weakness is its ability to account for almost any result so long as the exact location on the inverted U of the task in question is not specified in advance. The situation is further complicated, however, by the fact that the peak of the inverted U occurs at quite different levels of arousal for different tasks (Corcoran, 1965). This is intuitively reasonable; however, unless an objective means of assessing a task in advance is available, prediction of performance under stress becomes even more difficult. It seems unlikely that such an assessment can be made until the cause of the inverted-U relationship is known.

One possible explanation of the relationship lies in the suggestion made by a number of workers that an increase in arousal produces a narrowing of attention, with the subject concentrating more and more on the central features of the task and paying less and less attention to more peripheral ones (Easterbrook, 1959; Teichner, 1968). Perhaps the strongest experimental evidence for such a view comes from recent work by Hockey (1970 a,b) on the effects of loud noise on performance. In one of his experiments, Hockey (1970a) required his subjects to perform a centrally located tracking task, while at the same time monitoring a series of six small lights distributed on either

side of the central task at varying distances from the center. Occasionally one of these lights would be illuminated briefly; if the subject detected this he pressed an appropriate response button. Subjects were tested both in continuous loud noise and in quieter conditions. Overall tracking performance was significantly higher in the noise condition than in the control condition, which showed a decrement during the session. Detection scores on the peripheral task tended to deteriorate with increasing distance from the center. Noise exaggerated this bias by improving performance on the central lights at the expense of peripheral lights. When no central task was required, noise improved detection performance; thus it appears that noise does not simply impair peripheral vision.

In a subsequent experiment, Hockey (1970b) showed that subjects missed more peripheral signals in noise because they regarded them as less probable than central signals, not simply because of their peripheral location. A comparable result was recently reported by Cornsweet (1969) who used threat of electric shock to increase level of arousal.

Although experimental results show a clear effect of breadth of attention of stresses that may reasonably be assumed to influence the subject's level of arousal, so far there is no direct evidence that danger will have such an effect. Evidence that this is the case comes from a study by Weltman and Egstrom (1967) in which novice divers were required to perform a central task while monitoring a faint peripheral light. While the central task did not affect peripheral vigilance on the surface, during diving a distinct subgroup of the subjects emerged who showed much slower response to the peripheral lights, while showing no impairment on the central task. These subjects appeared to be more anxious that the other subgroup, which showed no deterioration under water, but unfortunately no objective measure of anxiety was available. This defect was remedied in a subsequent study (Weltman et al., 1971) in which a similar dual task was performed by naive subjects during a simulated 60-ft dive in a pressure chamber. After an explanation of the potential dangers and emergency procedures, the door of the pressure chamber was bolted and a rise in pressure simulated, although actual pressure did not change. Experimental subjects showed a clear anxiety response in terms of both increased heart rate and subjective ratings. They also showed a clear decrement in detection of peripheral light signals but no drop in performance on the central task, relative to an unstressed control group.

Wachtel (1967) and Moray (1969) provide general reviews of performance research in selective attention, while the review of this area by Howarth and Bloomfield (1971) concentrates on experiments involving attentional phenomena in search performance tasks. One specialized method of evaluating attention is shadowing performance tasks in auditory research. This topical area is thoroughly reviewed by Underwood and Moray (1971).

Larkin and Greenberg (1970), in studying the effect of uncertainty in presentation of auditory signals, conclude that selective attention may be a recognition phenomenon and not a detection phenomenon. They suggest that no amount of training should alter the detectability of a signal, but that differential experience, by practice, may enable a listener to recognize one tone more efficiently than another.

Typical studies invloving the number of stimuli presented are represented by the studies of Chuprikova (1969), Teichner (1971), and Rabbit (1964). Chuprikova found that increasing the number of signals possible in a representation had a continuously limiting effect on the preparedness of subjects to react. Teichner's thorough study on the effects of the number of possible signals on reaction time and probability of detection found that reaction time increased as a function of the number of possible signals and also that the probability of detection decreased as a function of increasing number of possible signals. Rabbit, using a sorting performance technique, found that scanning visual displays to find certain stimuli invloved the process of ignoring other stimuli. Specifically, he found that the number of irrelevant stimuli in a display affected both the speed and the accuracy of the sorting task.

Warm (1971) investigated partial reinforcement concepts utilizing a vigilance task. With a reaction time measure as a dependent variable and knowledge of results as one of the independent variables, he found that withdrawal of knowledge of results increased reaction time, and the effect of withdrawing the knowledge of results was greater in continuous than in partial reinforcement conditions.

Germana (1969) manipulated interstimulus intervals and found that when the interstimulus intervals were increased greater than 240 msec, no habituation was found. Germana feels that this may be due to the establishment of the stimulus arrival rate. He also observed that recall was unaffected up to interstimulus intervals of 240 msec.

Burgess and Hokansen (1968) as well as Krirohlavy (1968) found in performance studies they could use an increase in heart rate as an indication of increased effort or drive. While Kibler (1967) found that heart rate decreases were associated with improvements in performance of signal detection in a vigilance task.

The warning indicated by their seemingly conflicting results is further amplified by Wilkinson (1972), who suggests that physiological measures in performance tasks are not always general, but can in fact respond specifically to different task variables and to different people. For example, he found that changes in pulse volume relate to task difficulty, while changes in pulse rate relate to performance incentives.

## LIMITED CENTRAL PROCESSING CAPACITY

The principal recent development in this area of attention is the study by Allport et al. (1972) disproving the "single channel hypothesis" of human information processing. Their alternative hypothesis is that attention operates as if there were a number of independent special processes operating in parallel. Each process is limited in capacity per unit time and most processors may be turned to a single specific problem under conditions related to signal importance.

Erickson and Colegate (1971) relate selective attention to serial processing phenomena and short-term memory in briefly presented visual arrays.

The most recent attempt at the development of a broad theoretical structure of attention was Hebert's (1973) <u>Adaptation Level and Theory of Signal Detection.</u> Unfortunately, this theory is difficult to rebate to the structure of the mass of reported data.

## PSYCHOPHYSIOLOGICAL FACTORS

Psychophysiological concomitants of attention can be classified into two major categories of research: (1) those studies utilizing the electroencephalograph as the principal dependent variable, and (2) investigations into phenomena associated with the orienting reaction. Studies concentrating on the first category are discussed first; however, the bulk of the discussion will focus on the latter category.

Electroencephalographic Studies--Glaser (1963) has summarized the correlations between EEG findings and behavoir. Electroencephalographic studies have been primarily centered around observations on the contingent negative variation or evoked potential; however, some cogent observations are being made in situations involving operant conditioning or training of EEG components.

Since 1960 there has been growing evidence to support the theory that selective attention and selective perception have their neurophysiological basis in blocking irrelevant sensory impulses. Thus, sensory pathways of unattended modalities lose some degree of their capacity to transmit signals, while the attended modality may be facilitated simultaneously. Näätänen (1971) produced experimental results that show nonspecific anticipatory cortical activation preceding relevant stimuli. This, he argues, is the real reason for the greater amplitudes of potentials evoked by relevant stimuli. Hillgard et al. (1971) studied those evoked potentials during auditory signal detection and found that the detected signals evoked potentials several times the magnitude of unevoked potentials. He also found that detection threshold performance was identical with concurrent electrophysiological measures of threshold.

Wilkinson and Lee (1972) found data suggesting that the date positive wave is a return of prestimulus CNV to baseline and occurs selectively following stimuli and thus constitutes an EEG sign of selective attention. In a similar paradigm, Hillgard et al. (1974), using auditory blips to both ears, with one attended and the other ignored, found that the negative component of the evoked potential increased for the attended tone.

Donald and Goff (1971) reported that they have found EEG components of attention related to increases in cortical responsivity and dissociated from the contingent negative variations. Gale et al. (1971) utilized subjective estimates of alertness in a vigilance type task while manipulating signal expectancy. They found EEG changes correlated with changes in expectancy in the task.

Subjective reports of subjects in the Garrett/AiResearch laboratory (Wortz, 1971), corroborated by personal communication with other researchers (L. Fehmi, 1970; Kamiya, 1970) in the field concerning their findings, lend support to the hypothesis that readily monitored brain wave parameters are

correlated with awareness and attentional abilities. Fehmi (1970), for example, reports that the amplitude of brain wave potentials is observed to be correlated with the way in which visual stimuli are viewed. When artists were instructed to view and critically apprehend their field of vision, a low-voltage, fast-electroencephalographic activity was recorded from five brain loci: midline occipital, parietal and frontal lobes, and the right and left temporal lobes. When the opposite instruction was given to view the visual field with a gestalt orientation or in the attitude that would be assumed while actively engaged in painting, the electroencephalographic activity was characterized by high-voltage, slow waves in the alpha wave region of the frequency spectrum. A grasped, stationary, and critically viewed attentional field was associated with low-voltage activity while a flowing, integrative, gestalt-like approach to the attentional field was associated with high voltage activity.

Gale et al. (1972), in a study that failed in its main purpose, which was to replicate correlation between EEG, extroversion, time of day, and performance, did find incidentally that higher voltage EEG correlates with better signal detection. Consequently this vigilance task correlates with the contention of Wortz and Fehmi above.

In a recent important article, Beatly et al. (1974), studying operant control of occipital theta rhythms found that theta interferes with monitoring (vigilance) tasks and that training in theta suppression improves performance.

Barry and Beh (1972) found that duration of the desynchronization of the alpha rhythm of the EEG covaried with the stimulus intensity, whereas the magnitude of the desynchronization did not.

Invgar (1971), in a study of cerebral blood flow, arousal, and cerebral metabolism, suggests that the EEG correlates of arousal and desynchronization are correlated with an increase in cerebral blood flow. He even indicates that regional changes in cerebral blood flow are dependent on the type of cortical activity at each region.

Orientation Reaction (OR) Studies--Psychophysiological studies of attention also have proceeded from the direction stemming from the work of Sokolov, which is summarized in "Perception and the Conditioned Reflex," (1963) and reviewed by Lynn (1966).

This perspective of attention is in terms of what the Russian investigations denoted as the orientation--or what it is--reaction (OR). Essentially, the orientation reaction or reflex involves (behaviorally) the turning of the organism toward the source of a novel stimulus. In addition, however, there are a number of concomitant physiological components of this turning toward a stimulus. The physiological changes include pupillary dilation; reduction of threshold in all sensory modalities; increased electromyographic activity; faster, lower-amplitude EEG; peripheral vasoconstriction; cephalic vasodilation; GSR; delayed respiration followed by increased amplitude and lowered frequency; and slowed heart rate. These physiological changes occur regardless of bodily movement, and their occurrence is used to define the occurrence of an orienting reaction.

Essentially, stimuli that can initiate an OR are those that have signal significance, i.e., are either novel, intense, complex, or incongruous; are surprising; or produce tendencies for competing or conflicting reactions.

In addition to the OR, there are two other basic physiologic reactions of the same class that can occur in response to stimuli and must be distinguished from the OR. These are adaptive reactions and defensive reactions. Adaptive reactions refer to responses that have homeostatic or negative feedback reactions, e.g., vasodilation in response to thermal stress or pupillary dilation in response to decreases in illumination. The defensive reaction (DR), on the other hand, occurs in response to very intense or threatening stimuli and is essentially the startle reaction, which includes eye blink, cephalic vasoconstriction (instead of the cephalic vasodilation seen in the OR), and heart rate acceleration.

The other components of the OR occur in the DR without variance from the OR pattern. In addition to cephalic vasoconstriction and heart rate acceleration, another important difference between the OR and DR is that stimuli that will produce an OR will eventually habituate, and the OR will disappear. This is apparently not the case with the DR; it does not habituate. Although Wortz (1967, 1968, and 1969) has found evidence that upon repeated stimulation this response can develop from a DR into an OR, it is suggested by Wortz (1968) that high-stimulus intensities just below the DR threshold may at times evoke the DR if the general health or coping mechanisms of the organisms deteriorate.

The classic representation of the relationship of the OR and DR in terms of numbers of stimulus presentations and the intensity of the stimulation is reproduced from Sokolov (1963) and shown in Figure 2-1. This representation, showing that a constant intensity and tendency is to move from an OR to a DR with increasing number of stimulations, is contrary to the observations of Wortz who observed habituation of the DR evolving into an OR with cutaneous shock. The source of this discrepancy may be due to the type of stimuli employed or to levels of arousal. Sokolov observed the DR as a simple reflex and employed repetitions of a simple stimulus of fixed intensity, while Wortz observed a conditioned reflex response to a repetition of stimulus of fixed intensity.

It is apparent, however, that certain factors may vary the OR/DR threshold for a given stimulus intensity. It is suggested that psychophysiological consequences of presentation of stimuli near this threshold, for a given person and in terms of whether an OR or DR is elicited, may be indicative of fundamental aspects of the perceptual coping mechanisms of that person.

A recent study by Gogan (1970) measuring psychophysiological response to forces of different intensity provide data that tend to correlate with the previously described studies. One of Gogan's principal observations is a correlation between EMG components of the DR and EEG characteristics at the time of presentation of the signal stimulus (Figure 2-2). His data show that at slower EEG frequencies, the magnitude of the elicited startle response is lower. It can be argued from this data and that of Pilsbury and Meyerowitz that for stimuli of moderately high intensities, field-dependent individuals are more likely to produce a DR than field-independent subjects. Consequently, if disease does operate to alter the distribution of attention for exteroception, it can be hypothesized that this shift will be reflected in the mechanisms of the orienting and defensive reactions.
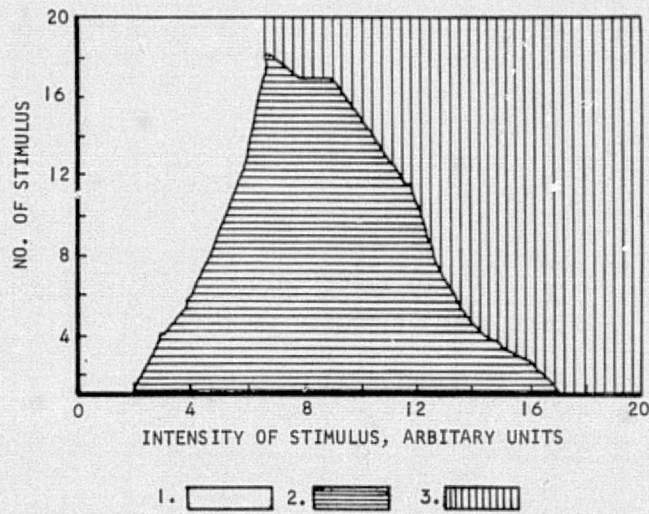
Figure 2-1.  Relationship between Orienting Reflexes and Defensive Reflexes Produced by Electrodermal Stimuli of Various Strengths
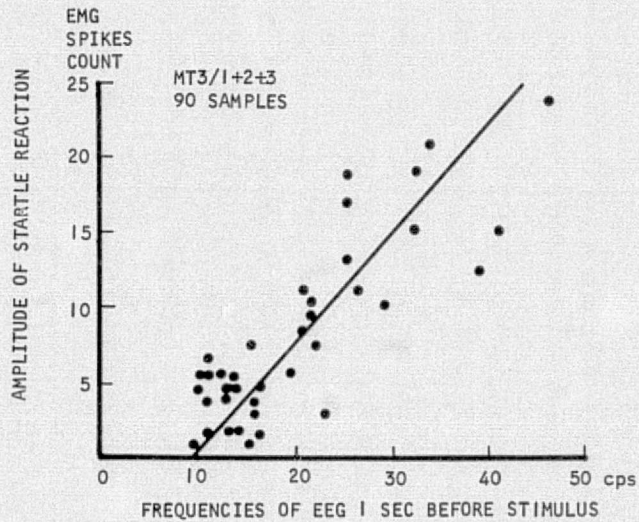


Figure 2-2.  Amplitude of the Startle Reaction Plotted Against Frequency of EEG Measured One Second Before Each Stimulus

S-71339

Specifically, it was felt that the most fruitful phenomena to investigate in this regard are the responses in the threshold region between the OR and DR. Thus it is hypothesized that the OR/DR threshold will vary with attentional load, decreasing as attentional load is increased.

Raskin et al. (1969) studied cephalic vasomotor and heart rate measures of the OR utilizing 80- and 120-db white noise signals. They always found cephalic vasoconstriction (as measured by forehead blood content or forehead pulse amplitude) to the stimulus, whereas heart rate differentiated between the two intensities. Heart rate deceleration occurred in conjunction with the 80-db stimulus while heart rate acceleration occurred with the 120-db signal.

Keefe (1970) utilized a 1000-Hz tone at 70 db, and observed a biphasic forehead pulse response that he interpreted as vasodilation followed by vasoconstriction. The magnitude of vasomotor response was found to be related to the prestimulus level, which corresponds to the law of initial values. He also observed that heart rate acceleration was associated with head pulse constriction.

Fantalova (1970) used a 1000-Hz tone stimulus and rheography for pulse volume measurements in an attempt to measure organ volumes as a consequence of the OR. He concluded that rheography could be used to detect the time of pulse arrival, but not organ volume.

In a study of procedural aspects of research on the OR, Gliner et al. (1971) found that alterations in order of stimulus presentation can produce orienting reactions.

Just as important as the occurrence of the OR, if not more so, is the rate of habituation of this response. Gabriel and Ball (1970), utilizing tactile stimuli, found that the OR magnitude would increase as the novelty of a stimulus increased. They also found a spread of OR habituation effect from a principal finger (which was stimulated) to adjacent fingers. Beideman and Sterm (1971) found that the occurrence of the orienting response observed at the start of a signal and the terminal orienting response (TOR) observed at the cessation of a signal are related to the content and duration of the stimulus. Essentially, they observed that the OR and TOR habituate in the same manner. The idea is that each successive stimulus provides less information; therefore, the novelty diminishes and consequently both OR and TOR diminish. They observed that the TOR habituates at a faster rate than the OR, presumably because after the onset of a signal its termination is more predictable than the stimulus onset. This determinability of the timing between signals also was studied by Germana (1969), who manipulated the interstimulus interval. He found that as the interstimulus interval increased, the rate of habituation decreased.

Intertrial interval effects were also observed for HR by Katkin and Nelson (1973). They found that a variable interval eventually resulted in habituation, while a fixed interval did not. They concluded that a "stimulus having signal functions will continually elicit the OR."

Maltzman et al. (1971) found that stress slowed the rate of habituation of the OR. In a unique set of experiments they found that undergraduates in a first experimental stress situation habituated more slowly than in a second situation, while graduate students habituated more rapidly in a first experimental situation than they did in a second situation just prior to taking a stressful examination. This second paradigm (with the stress in a separate area of the subject's life and affecting the rate of OR habituation) is relevant to the proposed research.

Coles et al. (1971) investigated personality factors and the OR, and suggested that neuroticism is positively related to the magnitude of the OR; whereas Koriat (1973) found no personality correlation in the responses to a tone, but individual differences were related to rates of habituation.

O'Gorman (1973), in a review of stimulus conditions and the OR, concludes that the only conditions that will produce an OR are increases in stimulus intensity or a change in stimulus modality.

That the issue of psychophysiological indices of behavior is cloudy is further advanced by Tunsky, Schwartz, and Crider (1970). They found rapid bidirectional cardiac responses to be sensitive to the attentional demands of the task and, importantly, that autonomic arousal-patterns are dependent on subsequent behavior. The accumulating evidence that autonomic arousal patterns are dependent on subsequent overt behavior has important implications for psychophysiology. The suggestion is that autonomic functions are closely allied with instrumental behavior and may play important roles in organism-environmental interactions. As an extension of the differential fractionation hypothesis, Lacey (1958) has suggested that cardiovascular feedback to the central nervous system may exert modulating influences on sensory and motor precesses. Increases in baroceptor firing consequent on increased HR or blood pressure are said to be "inhibitory" in terms of reducing electrocortical activation, raising motor thresholds, and dampening sensory acuity. Conversely, decreases in baroceptor feedback consequent on decreasing HR or blood pressure are said to be "excitatory" with respect to increasing cortical activation, sensory acuity, and motor readiness. These sorts of behavioral consequences of cardiovascular activity would be perfectly consonant with the shifting attention demands ...".

To add further complexity to the issue, Kearsley (1973) suggests that specific stimuli characteristics may affect OR/DR responses. Kearsley found, using newborns, HR decreases to 500 cps, 70-db with noise and a 2000-cps/80-db pure tone. On the other hand, HR acceleration was observed to a 1000-cps/90-db pure tone.

Gimberg and Freudy (1974), studying the OR, add to this issue by their concluding statement: "Why the plethysnographic components sometimes habituate to stimulus repetition and sometimes do not still awaits solution and challenges psychophysiologists."

Wycharles and Bartel (1972), faced with similar problems, decided that no one dependent variable and no assumption of attention as a unitary process provides an adequate explanation of attention.

The resolution to these issues may reside in the Churtie & Kotses (1973) observation of bidirectional conditioning of the cephalic vasometer response. Conditioning of classic OR and DR parameters clouds the basic concepts behind the OR and DR and certainly obviates much of the prior experimental procedures employed in psychophysiological investigation.

Lacey and Lacey (1964) reported on cardiac deceleration in a simple visual reaction time experiment. They found cardiac deceleration to a warning stimulus and cardiac acceleration to the reaction time signal stimulus. These observations were confirmed by Graham and Clifton (1966), who, in addition to the heart rate deceleration to the warning stimulus, observed acceleration both before and after the response.

While studying vigilance tasks, Kibler (1967) found a correlation between the signal detection efficiency and the magnitude of the cardiac deceleration.

The relationship between heart rate and signal stimuli was further explored by Coles et al. (1972). They also found that a warning signal produced heart rate deceleration and that the signal stimulus produced heart rate acceleration. When they instructed their subjects not to respond to the signal stimulus, the heart rate still accelerated, but at a lower rate than when a response was required. They suggested classifying stimuli as imperative or warning, based on the direction of the change in heart rate.

In linking the cardiac components of the orienting and defensive reflexes to vascular components, Hare (1972) found that heart rate deceleration was accompanied by cephalic vasodilation while heart rate acceleration was accompanied by cephalic vasoconstriction. Thus, although he replicated the Sokolov model, he made his observation by separating his subjects into types based on their heart rate responses to anxiety-arousing accident scenes. He suggested that the classic patterns of cardiovascular activity occur in only some subjects and only under some conditions and that they may be obscured by undifferentiated group data.

Hare defined his optimal grouping of subjects as accelerators, decelerators, and medium decelerators.

In an earlier report Hare et al. (1971) reported on autonomic responses to effective visual stimulation consisting of female figures, homicides, and ordinary objects. They found the largest heart rate deceleration in women shown slides of nude females and the largest vasomotor response in women shown slides of homicides. The converse was true for male subjects.

Carrol (1971), using effective visual stimuli to study forehead vasomotor responses, found an initial decrease in forehead pulse amplitude to all stimuli, followed by an elevation in amplitude above the baseline level across a period of 15 seconds.

Wilkinson et al. (1972) added confusion to this area of study by finding that different psychological measures differ in reflecting apparent arousal. In studying performance and arousal as a function of incentive, information load, and task novelty, he found that pulse volume responded to changes in task difficulty while pulse rate responded to incentive.

Zeiner and Schell (1971), using skin resistance as a parameter, found faster learning and higher orienting responses to innocuous stimuli than to noxious stimuli. They suggested that the response to these two classes of stimuli may involve different physiological processes.

Use of the GSR as an OR-dependent variable has been studied with varying results by Zeiner (1970), Ohman (1971), Siddle (1972), Fuhrer et al. (1973), and Furedy and Schiffmann (1974). Principal observations from these GSR studies are that variable intertrial intervals operate to increase OR's, fast habituators are slow performers, and that a positive correlation exists between conditionability and OR response magnitude.

In an important paper, Kreitler and Kreitler (1972) relate the orienting response to cognitive processes i.e., processes involved in the production of meaning. Their contention is that cognitive processes allow a better understanding and more precise prediction of human behavior than other variables. They introduce the concept of cognitive orientation to suggest the cognitive nature of the orienting process. Their primary assumptions are that (a) attempt to achieve cognitive orientation (CO) is a primary tendency, (b) human behavior is altered by cognitive orientation, and (c) information about CO allows the prediction of the course of ensuing behavior.

A few definitions are required in order to prepare for a brief description of this model and its relationship both the the work previously cited and to the work evolving under this contractual program. These definitions are fairly well evolved in the paper by Kreitler and Krietler and their derivations will not be reiterated here.

First is the idea of meaning dimensions (13 lexical and 10 symbolic dimensions are evolved on the basis of experimental data), which are the rules for the categorizing process that is applied to input stimuli. These rules function as an "address" to direct scanning and matching to neuronal models. Denotive meaning is then the result of a match between input stimulus and the neuronal model. The term "meaning action" is applied to this selection, retrieval, and matching process. The role of meaning action then is to establish meaning values of a kind that enable a defensive reaction (DR), a conditioned response (CR), and an unconditioned response (UR) or an adaptive response (AR) to be elicited. If meaning action fails, i.e., none of the above is obtained, an orienting response (OR) is released. Sufficiency of a denotive meaning then is the habituation of the OR and the elicitation of an AR, CR, DR or UR (UR other than the OR).

When the elicited response is insufficient, the molar behavior is mobilized. This occurs when:

(a)   In spite of the OR, no new information about the stimulus object is achieved and the information available is inadequate for a denotative meaning.

(b)   Denotative meaning was established and a CR was produced, but that method of coping was inadequate.

(c)  The pattern of denotative meaning includes a value that expresses
     the requirement for molar behavior.

The meaning dimensions most likely involved in determination of denotative
meaning are the lexical dimensions of sensory qualities, contextual allocation,
similarity and contrast, and potentialities for action.  Evidence that the
application of these meaning dimensions for stimulus recognition are simultan-
eous are provided by Allport et al. (1972) and Neisser (1967).

Although the theoretical paper by the Kreitlers is developed toward the
idea of being able to predict behavior from beliefs and belief clusters (and
some evidence is provided for this contention), the relevant point for this
project is the interrelationship of OR's and cognitive processes.

# SECTION III

## EXPERIMENTAL PARADIGM AND DESIGN

In this psychological assessment program, the test was similar to that used in the previous pilot study investigation documented in AiResearch Report 73-9045. The subject was instrumented as described in Sections IV and V of that report, then he was seated at the keyboard of a cathode ray tube (CRT) display unit. He wore earphones through which a probe stimulus tone was applied. The subject was instructed to play a visual matrix game that consisted of counting specified symbols or groups of symbols in a 20-by-20 alphanumeric matrix displayed on the CRT. He was given a time limit for counting and indicated his answer by entering a number on the keyboard. Under some conditions, the subject was instructed to turn off the tone by pressing a particular key on the keyboard. Under other conditions, he was unable to turn off the tone.

### INDEPENDENT VARIABLES

The following independent variables were explored in this experiment:

(a) Visual matrix game type

(b) Probe tone stimulus intensity

(c) Inclusion or exclusion of a reaction time contingency

(d) Imposition of time limits for performance of the visual matrix game task

(e) Amount of training on the tasks

Visual matrix (VM) game 1 consisted of counting the occurrences of a single given character or number in the alphanumeric matrix. VM game 2 consisted of counting the occurrences of vowels in the matrix. VM game 3 consisted of counting the occurrences of letters in a randomly selected, 5-character interval, e.g., the occurrences of letters between H and L, inclusively.

The probe tone stimulus condition consisted of presenting to the subject, through a headset, a pure tone of 90, 100, 110, or 120 db intensity. The pure tone was presented over a white noise background of 80-db intensity.

Under some test conditions, the subject was required to turn off the auditory probe stimulus as quickly as possible. This was done by pressing a button on the CRT keyboard. Under other conditions, this interrupt button was not available and the tone was self-terminating after 5 sec.

Each test was run under time limits; 80, 100, and 120 sec were used as maximal allowable times to complete the VM game task.

All subjects were tested over a 3-day period.

Figure 3-1 illustrates the experimental design for a given day of train-
ing. Each of the 18 subjects were run under each of the combination of condi-
tions represented by this figure. Included in this figure are the test
conditions of no task, i.e., the subject sat passively while data was recorded.

Each subject was tested under each of these conditions on three different
days.

## DEPENDENT VARIABLES

Measurements in this experiement were made on task performance, reaction
time, and physiological parameters.

### Task Performance

Task performance, the principle dependent measure for the VM game task,
was determined in terms of the $\Delta$ percent of the count entered by the subject
and the actual count in the matrix

$$(\Delta \text{ percent} = \frac{\text{subject's count - actual count}}{\text{actual count}}).$$

### Reaction Time

Under test conditions requiring a reaction-time task, the time difference
was measured from the onset of the auditory probe stimulus until the interrupt
button was pushed.

### Physiological Parameters

The measured physiological parameters were heart rate, head plethysmograph
(HPG) pulse amplitude, finger plethysmograph (FPG) amplitude, and rheoenceph-
alograph (REG) pulse amplitude. In addition, time intervals were measured
between the occurrences of FPG-ECG, HPG-ECG, REG-ECG, REG-FPG, REG-HPG, and
FPG-HPG. The rationale behind exploring these time differences is that they
are likely to be systematically perturbed by vasomotor response patterns
(refer to the discussion in Section II).

It should be noted that some dependent variables (DV) were not measured
under all conditions due to the mutually exclusive nature of particular DV's
and the test conditions. For example, reaction time was not measured under
the no-probe stimulus condition and the no-reaction time task condition. The
designation of test conditions is described in Section IV.
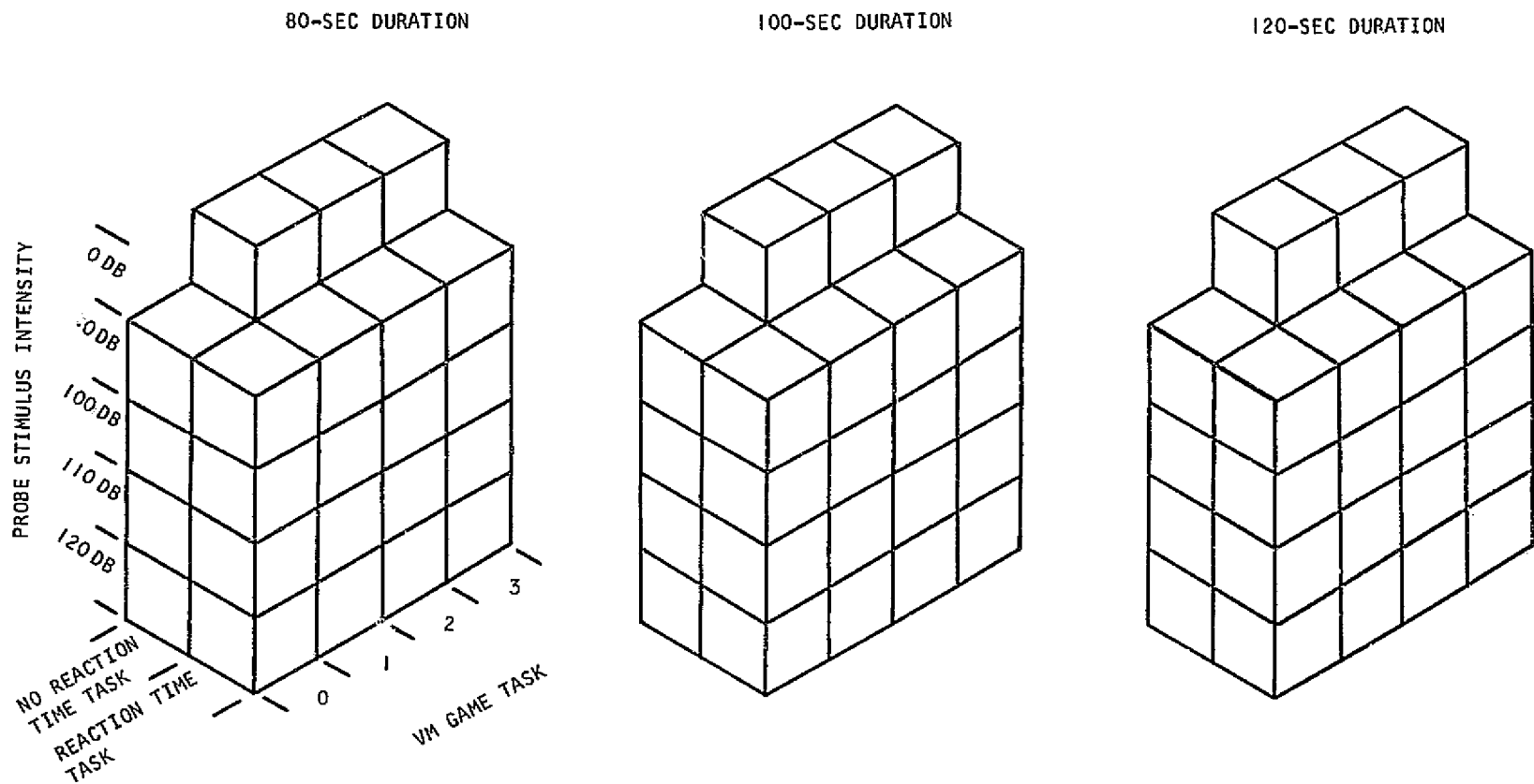
Figure 3-1. Experimental Design

SECTION IV

PROCEDURES

## SUBJECTS

The subjects were 18 male employees of The Garrett Corporation who were between approximately 25 and 55 years of age.

## HOOKUP

Photoelectric pulse transducers (Narco, type 323) were attached to the index finger of the nondominant hand and to the forehead (approximately 1-1/4 in. above the top of the right eyebrow). Three silver/silver biodes were attached to the upper, lower, and central sternum for electrocardiogram recording. Sponge biodes soaked in saline solution were affixed to the left and right temples for rheoencephalogram recording. Further details on hookup are discussed and illustrated in Appendix A, pp. A-15 through A-19.

## INSTRUMENTS

System specification sheets, design details, method of calibration, and method of operation are detailed in Section V and Appendix A. The rheoencephalogram (REG) signal was preconditioned with an impedance converter (Biocom, model 2991). Signals from the finger plethysmogram (FPG) and head plethysmogram (HPG), the electrocardiogram (ECG) signal, and the preconditioned REG were amplified and conditioned by the AiResearch psychological assessment signal conditioner. Then the data was graphically recorded, generally in analog and pulse form for test monitoring purposes, using an Offner-Beckman type S Dynagraph. For future computer analysis, the data was recorded by a Honeywell model 7600 tape recorder.

A Texas Instruments model 960-A computer was used in presentation of experimental stimuli to the subjects. Start and stop of visual matrix (VM) games, start and stop of auditory probes, and level of auditory probes also were programmed by this computer and recorded on the polygraph and the tape recorder. A Teletype was used to program the computer for display of stimuli to the subject, and to record type of matrix presented, subject's answer to the matrix game, correct answer to each matrix displayed, and reaction time to all auditory probes presented. The VM games were presented to the subject on a CRT. His answers were typed on the CRT keyboard.

## VISUAL MATRIX GAMES

The CRT display included directions (i.e., VM game 1: count the occurrences of a specified item in the matrix; VM game 2: count the occurrences of the numbers or letters in a specified set; and VM game 3: count the vowels). Also in the CRT display were: game time limit (80, 100, or 120 sec), a 20-by-20 alphanumeric matrix (scrambled for each presentation with random number generators in the computer), a countdown clock in the lower left corner of the CRT showing the seconds left in the game, and a space in the upper left corner of the CRT showing the subject his typed answer.

To get used to the CRT keyboard and display, all subjects received about 5 min of practice at the beginning of their first day of participation. Figure 4-1 shows the instrumented test subject seated at the test console. The physiological instrumentation, CRT, keyboard, physiological signal conditioner, and the test computer also can be seen in this photograph.

## TEST CONDITIONS

Each session contained six conditions. All subjects received three sessions of six test conditions at intervals of 24 hr or more. Completion of the six conditions in one session took approximately 2 hr. All single sessions were administered during a single time period.

Condition 1 included a 10-min stabilization period and then 2 min of recording with no other experimental contingencies.

Condition 2 included exposure to a randomly generated auditory-probe tone sequence (both time interval and tone volume were randomly controlled), with recording occurring for 2 min.

Condition 3 was the same as condition 2, except that subjects were told to turn off the auditory probes as rapidly as they could by pressing the interrupt (INT) button on their CRT keyboard.

Condition 4 included a sequence of 12 VM games displayed on the CRT without auditory distraction. Three time limits were used in groups of four games, and the order of the time limits was determined randomly. Within any given time limit, four games were presented in random sequence. Of each four-game sequence, at least one game was selected from each of the three game grade levels. It was then ensured that each level of VM-game difficulty would occur for each time limit.

Condition 5 was the same as condition 4, except that the VM game was presented to the subject with auditory probes at random loudness levels and time intervals. The auditory probes turned off automatically after 5 sec.

Condition 6 was the same as condition 5, except that (in addition to the VM game) the subject was told to turn off the auditory probes as quickly as he could, using the INT button on the CRT keyboard, at the same time playing the 12-game matrix sequence.

Table 4-1 illustrates these test conditions and the dependent variables.

## AUDITORY PROBES

Auditory probes were presented in both ears through a headset worn by the subject. Four loudness levels were used for these probes: 90, 100, 110, and 120 db. All tones were 1656 Hz frequency. The order of presentation and the time interval between probes were random. Order was determined by a randomly ordered sequence written into the presentation program; time intervals were
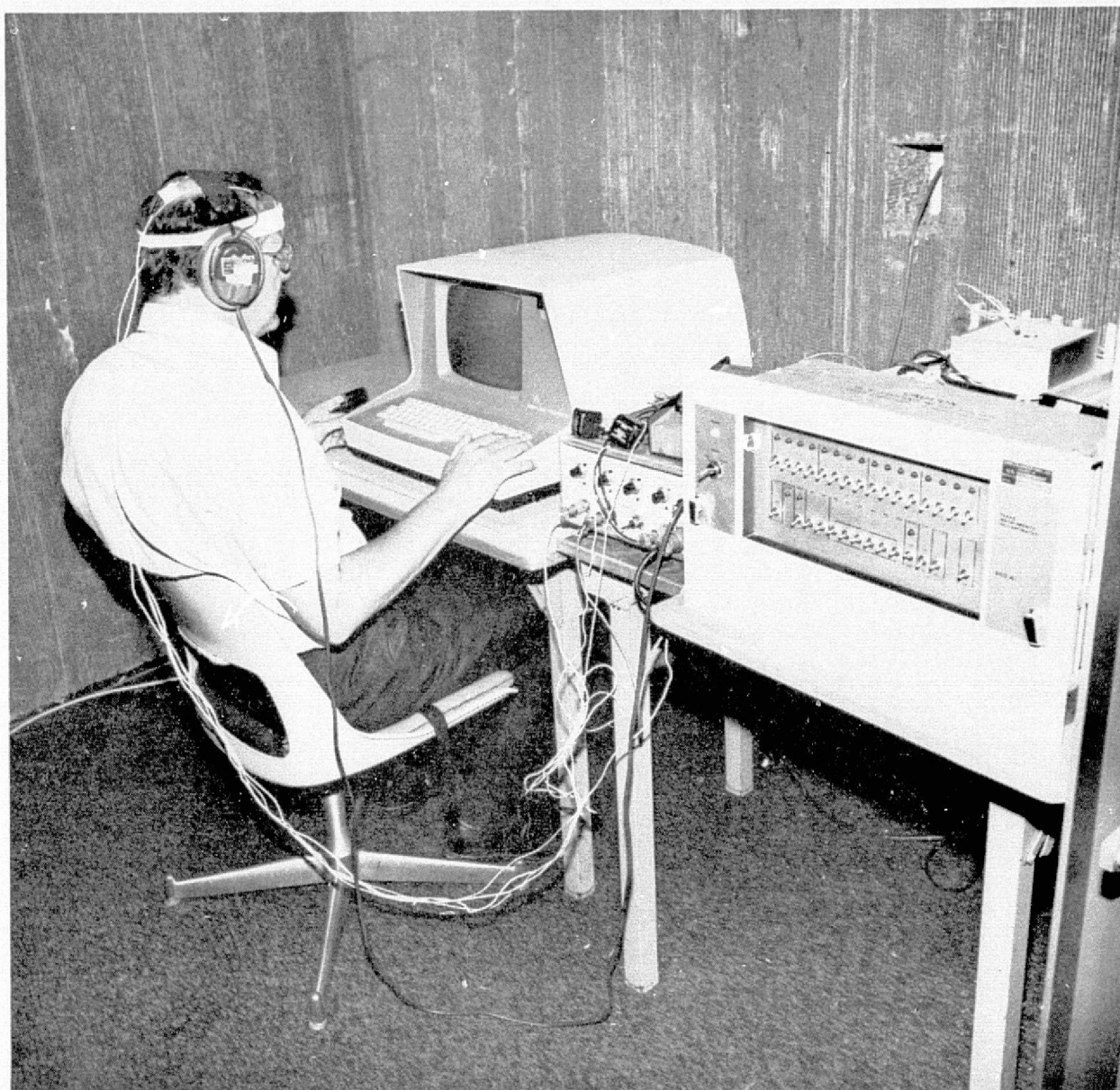
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Figure 4-1.  Test Subject at Test Console

TABLE 4-1

TEST CONDITIONS AND VARIABLES

| Test Condition | Independent Variables | Dependent Variables |
|---|---|---|
| 1 | No experimental treatment; subject passive and at rest | All physiological dependent variables (DV's) |
| 2 | Auditory probe stimulus; subject passive | All physiological DV's |
| 3 | Auditory probe stimulus and reaction time task | Reaction time; all physiological DV's |
| 4 | VM game and task duration | Performance $\Delta\%$; all physiological DV's |
| 5 | VM games, task duration, auditory probe stimulus (no reaction time) | Performance $\Delta\%$; all physiological DV's |
| 6 | VM games, task duration, auditory probe stimulus and reaction time task | Reaction time, Performance $\Delta\%$, All physiological DV's |

controlled by randomly generated numbers in the presentation program. The auditory probes automatically turned off after 5 sec unless turned off earlier by the subject.

RANDOMIZATION

Condition 1 always occurred first. Conditions following the first were sequenced using a table of random digits.* The experimenter first entered the table from the top and selected the first previously unused digit to determine which block of the table to use. Then the experimenter entered the block, and the order of conditions was determined. Next, for conditions 4, 5, and 6, the order of time periods was determined (for this purpose, A was represented by 1, B by 2, and C by 3). Finally, for each of these time periods the four-game sequence within the period was determined. Order of auditory probes was governed by a randomly generated sequence of 42 appropriate digits, written into the computer presentation program. Time interval between probes, search item or items, and scrambling of the matrix between games were controlled by random number generators in the computer.

EXPERIMENTAL SETTING

Experimentation occurred in a sound insulated, airconditioned room. The subject worked at the CRT in one corner of the room. The experimenter in charge of monitoring and recording physiological data was in a second corner

* Cox, 1958, pp. 299-300

of the room. Another experimenter, who instructed the subject, ran the tele-
type, and monitored the recording of performance data, was in a third corner
of the room.

## DATA COLLECTION

The subject answers to each matrix were recorded on the Teletype print-
out and on paper tape, with the correct answer, VM game designator, time limit,
intensity of each auditory probe, and reaction time to each auditory probe.

Physiological data, including ECG, REG, and finger and head plethysmographs
were recorded in analog and pulse form on a Honeywell 7600 tape recorder and
on paper on a type-S Offner-Beckman Dynagraph (refer to Section V).

# SECTION V

## INSTRUMENTATION

### COMPARISON WITH PREVIOUS PHASE OF PROGRAM

The instrumentation used in the present phase of the psychological assessment program is similar to that used in the previous phase of the effort. Figure 5-1 is a block diagram of the instrumentation system. The previous instrumentation is described in AiResearch Report 73-9045, 14 March 1973. The important differences and modifications in the instrumentation are outlined briefly as follows:

(a) In the present program, commercial plethysmogram sensors were used. Previously, sensors made in the laboratory were employed.

(b) Previously, test data were recorded on an eight-channel strip-chart recorder (Beckman Dynagraph) and data reduction was accomplished by hand. In the present work, test data were recorded on a 14-channel tape recorder and were subsequently analyzed by a digital computer.

(c) The recording of time relationships among the four primary physiological parameters (ECG, FPG, HPG, and REG) in the present work was accomplished by modifying the instrumentation so that shaped pulse signals were generated for each of the primary parameters. These pulses were recorded on tape and subsequent computer analysis was used to derive the various time relationships. In the previous work, these time relationships could not be extracted from the recorded test data, due to the different recording technique attempted. In addition to the pulse signals, analog signals corresponding to FPG, HPG, and REG were recorded.

(d) The quality of the instrumentation was improved for the present investigation. In earlier work, the two plethysmograph signals and the REG signal were almost useless. In the present work, all four primary signals were of useable quality.

### DESCRIPTION OF SENSORS

The four primary physiological parameters or variables that were measured in the present work are denoted by ECG (electrocardiogram), FPG (finger plethysmogram), HPG (head plethysmogram), and REG (rheoencephalogram). These four primary variables are related to the pulsing flow of the blood through the heart, in the finger, in the skin of the forehead, and within the skull cavity.

The ECG sensors are three silver/silver biological electrodes, or biodes, attached to the subject's chest with double-sided tape. Electrical contact with the skin is made through a jelly-like medium, produced especially for the purpose. One biode is used as a reference electrode. The other two are
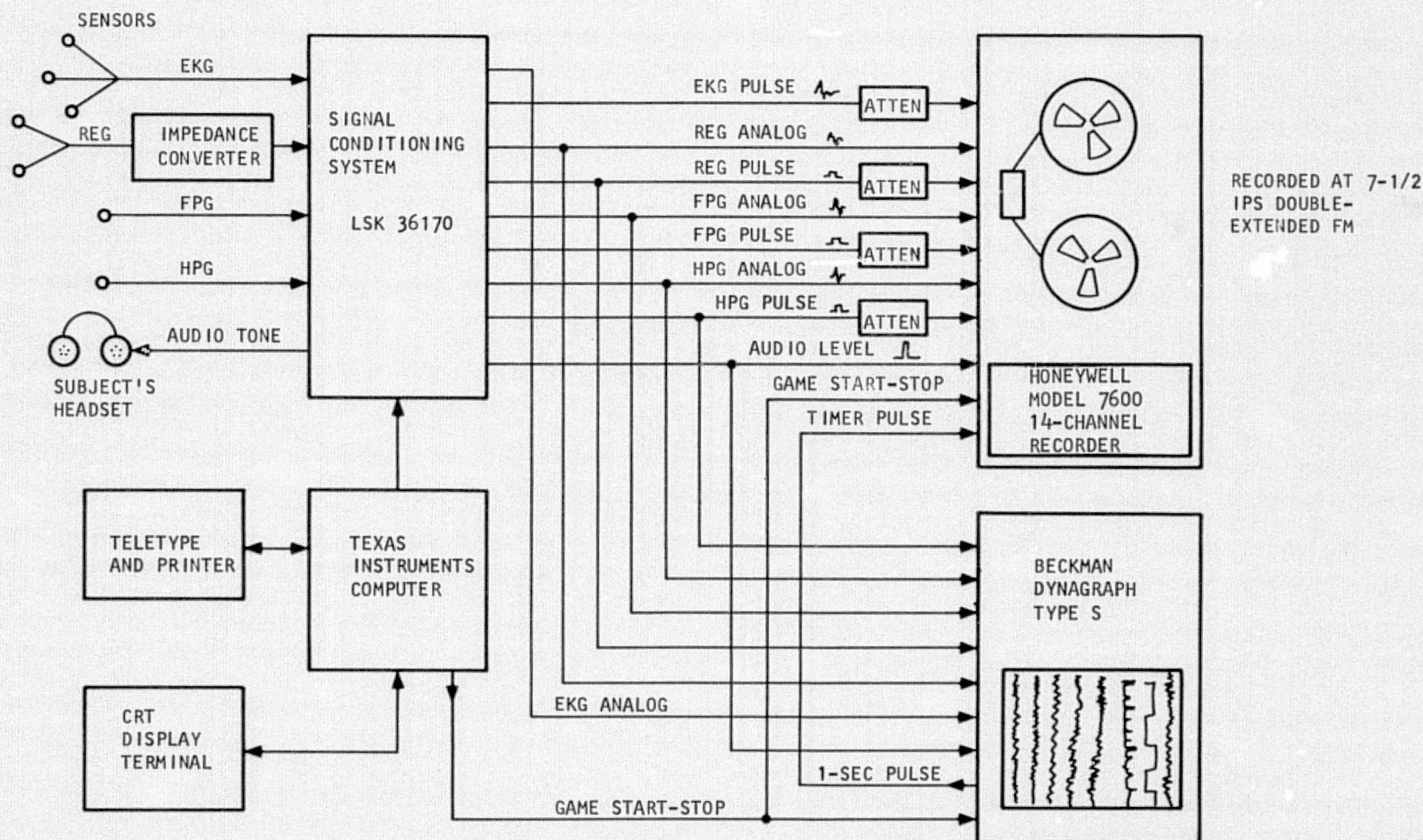
Figure 5-1. Block Diagram of Instrumentation System

connected to the plus and minus signal inputs of the ECG amplifier (see Dwg. LSK 36171, Appendix B), while the reference biode is connected to the neutral input. The arrangement of three biodes is employed to achieve rejection of common mode voltages, which are in the range of 10 to 100 mv, and to detect and measure the true ECG voltage of 0.1 to 2 mv peak.

The FPG and HPG sensors are commercial plethysmograph instruments, manufactured by NARCO Bio-Systems, Inc., of Houston, Texas, designated by the manufacturer as Photoelectric Pulse Transducer type 323. These instruments operate on the principle of light absorption by tissue immediately beneath the skin. Each sensor consists of a light source and a light detector mounted adjacent to each other, but optically separated in a rectangular body that is attached to the skin by tape or a cuff. The available optical path from the source to the light detector is through the skin and underlying tissue of the subject. The attenuation of the light is a measure of the blood concentration in the capillaries under the skin. The FPG sensor was attached to the index finger of the subject's cff hand (i.e., left hand of a right-handed subject, and vice versa). The HPG sensor was attached to the subject's forehead.

The plethysmograph photoelectric sensors were connected to the signal conditioning module through preamplifiers, supplied as part of each instrument. One cable connected the detector to the preamplifier. Another cable connected the preamplifier to the signal conditioning module (see Dwg. LSK 36170, Appendix B). The circuitry of the signal conditioning module was modified to accommodate the NARCO preamplifiers, as described in Section VI.

The REG transducer consists of two electrodes and a commercial impedance bridge and signal conditioning unit, manufactured by BIOCOM, Inc., of Culver City, California. The designation is Impedance Converter model 2991. This battery-powered unit consists of an oscillator, an impedance bridge circuit, and a preamplifer. The two electrodes are placed on opposite sides of the subject's head in such a manner that the electrical impedance of an electrical path through the interior of the skull constitutes one arm of the impedance bridge. The change in head impedance associated with the pulsation of blood in the brain changes the bridge balance and produces the REG signal. In the unit used in the present work, the oscillator frequency was about 75,000 Hz. The preamplifier contains a detector and low-pass filter, so that the envelope of the 75-kHz unbalance signal becomes the REG signal.

### SIGNAL CONDITIONING EQUIPMENT

In the present investigation, the signal conditioning module accepted the four primary variables (ECG, FPG, HPG, and REG) as low-level analog voltages. The output of the module was eight signals of amplitude suitable for recording on magnetic tape. Four of these signals were obtained by amplifying the four analog input signals to suitable levels. The other four signals were square-topped pulse signals, whose rising edges coincided in time with the steeply rising portions of the corresponding analog voltages just before these signals achieved their peak values. Each pulse signal was generated by a one-shot pulse generator circuit triggered by a discriminator. The inputs to the discriminator (a voltage comparator) were the respective

analog signal and a dc bias voltage derived from an adjustable potentiometer on the panel of the signal conditioner. The pulse generator produced an approximate 4-sec pulse. The test technician adjusted the potentiometer settings to the highest positive voltage settings that would result in a regular train of pulses. These settings had to be changed not only for each subject, but several times during the course of testing a given subject because of the variations in amplitude of the corresponding analog signals.

Although the signal conditioning equipment generated four analog and four pulse signals corresponding to the four primary variables, one of the analog signals (the ECG analog) was not recorded.

The signal conditioning equipment also provided two other signals for recording on tape. One of these was the envelope of the auditory stimulus tone applied to the subject. This signal had one of four possible amplitudes, corresponding to tone levels of 90, 100, 110, and 120 db. The other signal indicated the starting and stopping of each game. These two signals originated within the Texas Instrument model 960 computer.

The signal conditioning equipment was the same basic unit that was used in the previous investigation, with some modification. Additional output jacks were mounted on some of the circuit boards to obtain the desired analog and pulse signals for recording. The circuit board formerly used for the plethysmograph transducers was replaced by a new board to accommodate the NARCO type 323 Photoelectric Pulse Transducers. The previously used circuit (see Appendix B, Dwg. LSK 36174) provided low-voltage power and bridge completion arms for the two AiResearch laboratory plethysmograph photoelectric sensors. The NARCO transducers require only the operational amplifier supply voltages of +15, -15, and 0 vdc. They do not require bridge completion arms, for these components are incorporated in the preamplifier.

In the previous investigation, it was found that the REG signal was unuseable because the signal of interest was masked by artifacts due to the twitching of the subject's scalp and eyebrow muscles. The advice of the manufacturer of the REG impedance converter was sought. It was recommended that different electrodes be used. In the previous work, the REG electrodes were silver/silver biodes, the same as the ECG electrodes. The manufacturer recommended the use of pieces of sponge soaked in salt water. Electrodes of this type were fabricated in the laboratory and were used with satisfactory results in the present investigation. The electrodes were pieces of sponge of the type used for cleaning soldering irons.. Each sponge was cut to form a piece approximately 10 sq cm in area and about 0.5 cm thick. An aluminum tab was cemented to each sponge and a length of insulated 22-gage hookup wire was crimped to it for electrical connection to the impedance converter. The salt solution used was a nearly saturated mixture of NaCl in distilled water.

Even with the sponge electrodes, the REG signal required amplification to a level suitable for recording. In setting up the signal conditioning equipment for the previous investigation, it had been assumed, from lack of knowledge or experience, that the REG signal from the impedance converter would not require additional amplification. It was discovered in the present

investigation that the unamplified REG signal had a peak amplitude in the range of 0.050 v. Accordingly, it was decided to increase the gain of the REG preamplifier (see Appendix B, Dwg. LSK 36175). The increase in gain was accomplished by changing the values of resistances R4 and R6 from 10,000 ohms to 240,000 ohms each. The gain was increased from unity to 24.

## RECORDING METHOD

Three recording devices were used to record test data: a Lear-Siegler teletype machine, a Honeywell model 7600 magnetic tape recorder, and a Beckman eight-channel Dynagraph recorder. The Teletype machine was connected to the Texas Instrument model 960 computer and recorded the following information: game type, game score (both the correct answer and the subject's answer), coded test conditions, and the duration and level of each audio stimulus tone applied during a game. The tape recorder was used to record the seven physiological signals mentioned earlier (ECG pulse, FPG pulse and analog, HPG pulse and analog, REG pulse and analog), the stimulus tone envelope, and the game on-off signal. Double-extended FM recording was used on all nine channels. The Dynagraph was used merely as a backup to the tape recorder and as an ongoing test monitor. Eight of the nine channels of taped data could also be recorded on the Dynagraph. It turned out that the Dynagraph recordings were not needed in the subsequent analysis of data.

The signal levels were adjusted by setting the gain on each tape recorder channel to achieve a reasonable amplitude of the recorded signal. The maximum amplitude that can be recorded without distortion is 10 v peak. Due to the large variation in amplitude of the analog signals, the gains of their channels were set to achieve signal recorded amplitudes of approximately 1 or 2 v during quiet (non-testing) periods for the subject. The constant-amplitude pulse signals (four physiological parameters and game on-off) were set for amplitudes of about 2 v. The audio tone envelope channel gain was set so that the largest amplitude, corresponding to 120 db, was 6.3 v. The other amplitudes were thus 2.0, 0.63, and 0.20 v, respectively, for levels of 110, 100, and 90 db.

The transducers for the four primary physiological variables were not calibrated, and no calibration signals were recorded on tape. At the beginning of the investigation, it was decided not to attempt comparisons of one subject's response with another in absolute terms. Rather, the varying response levels (amplitudes, rates, and time delays) of a given subject under varying conditions of mental stress were recorded on a comparative basis. Each subject was recorded under a reference or quiescent condition. Subsequently, the various response levels were compared with each other and with the reference condition. Intercomparison of subjects was done on the basis of each subject's own responses relative to his own reference.

The data were recorded at a 7 1/2-ips tape speed on 7200-ft tape reels. Each reel could accommodate data from the testing of two subjects on a given day, because each test session lasted about 2 hours, with perhaps 80 to 90 minutes of actual recording time. In addition to the nine FM data channels, a voice channel was recorded to enable the test technician to note verbal

comments about the test, and another channel was used to record timing pulses for later correlation between the tape recording and the Dynagraph record. Since it was not necessary to use the Dynagraph records, the recorded timing pulses were not used.

Electrical connections between the signal conditioning module and the tape recorder were made through a Jones terminal strip attached to the module.

Figure 5-2 is a photograph of the instrumentation system. This photograph shows, from left to right, the instrumented test subject, the physiological signal conditioners, the programming computer, the Dynagraph recorder, the tape recorder, and the rack containing signal conditioners for the tape recording.
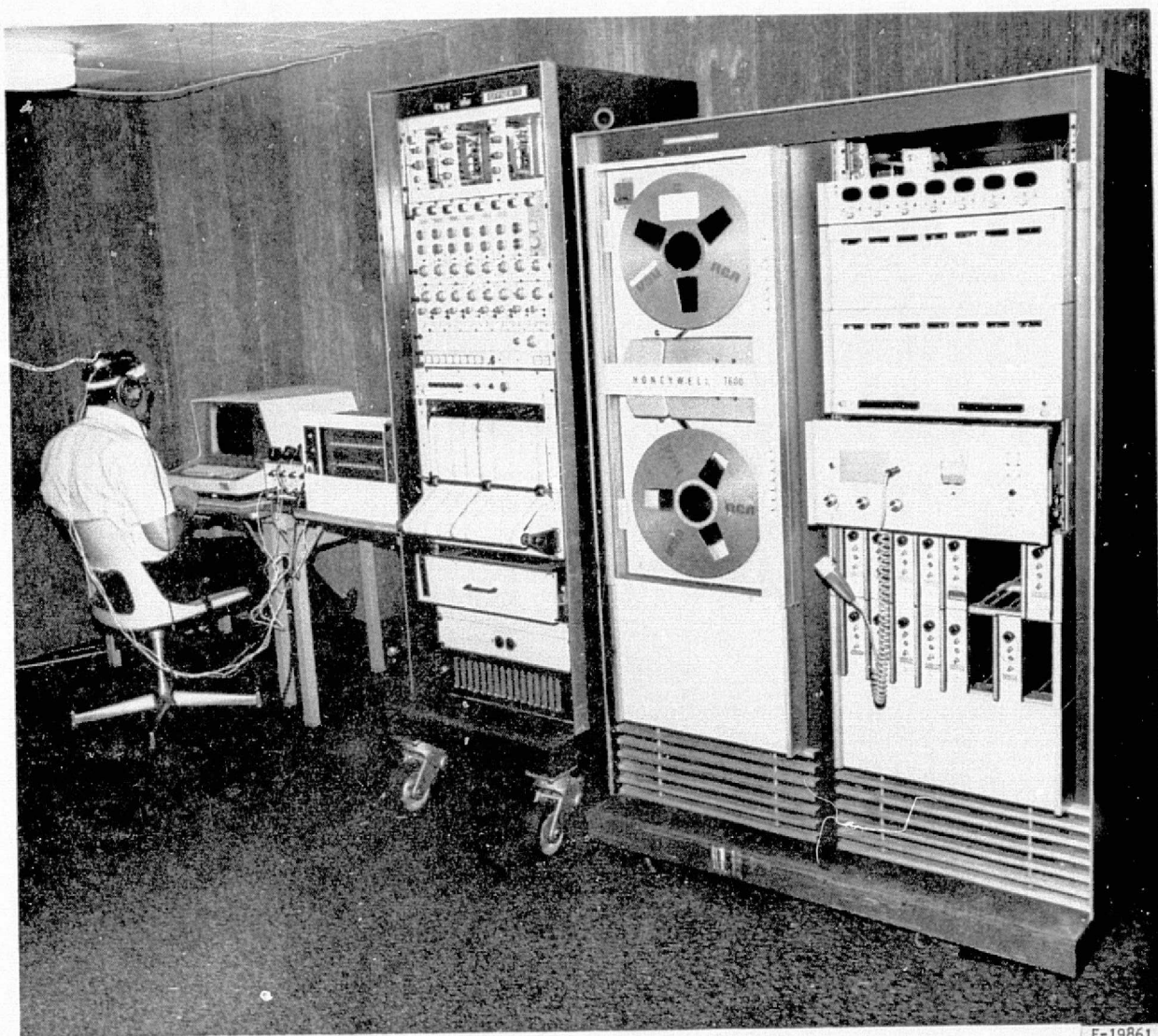
Figure 5-2. Instrumentation System

SECTION VI

DATA ANALYSIS


Performance and reaction time data were collected for each subject under each experimental condition. Then these two dependent variables were treated by ANOVA programs to ascertain the effects of the independent variables. Included in the analysis are performance and reaction time changes as a function of the learning process across the three test days.

On the other hand, physiological parameters were subjected to various data reduction and analysis steps as reported in the following paragraphs. Because of the magnitude of the data reduction task, the physiological data reported in this document is restricted to the third day of training.

## CONVERSION TO DIGITAL FORM

The first step in the process of automatic machine analysis of physiologically based test results was the conversion of recorded data on magnetic tape to digital form on another magnetic tape. All nine channels of recorded signals were simultaneously digitized by means of the AiResearch META-4 computer system. The sampling of data was synchronized by the leading edge of each ECG pulse recorded. The audio stimulus tone signal and the game on-off signal were sampled within 1 msec after the occurrence of the ECG pulse leading edge. Each of the three analog signals (FPG, HPG, REG) was sampled at a high rate following the ECG pulse until the maximum value was attained. This maximum value was retained and recorded on the digital tape. Finally, the times of occurrence of the leading edges of the other three pulse signals (FPG, HPG, REG) were recorded on the digital tape. The times of occurrence of the four pulse signals were recorded with a precision of 1 msec.

## METHODS OF DATA AVERAGING

It was decided to express the seven recorded physiological variables in terms of ten parameters, each expressed as a time series. These ten parameters are as follows:

$P_1$ = ECG pulse rate, expressed as the reciprocal of the time interval between two successive pulses

$P_2$ = Time interval between corresponding ECG and REG pulses

$P_3$ = Amplitude of REG analog signal

$P_4$ = Time interval between corresponding ECG and FPG pulses

$P_5$ = FPG amplitude

$P_6$ = Time interval between corresponding ECG and HPG pulses

$P_7$ = HPG amplitude

$P_8$ = Time interval between corresponding FPG and REG pulses

$P_9$ = Time interval between corresponding HPG and REG pulses

$P_{10}$ = Time interval between corresponding HPG and FPG pulses

There are certain algebraic identities among these ten parameters. Thus, $P_2 = P_6 + P_9$; $P_9 = P_8 + P_{10}$; and $P_4 = P_6 + P_{10}$.

Each parameter was averaged by two methods: (1) the 20-sec mean and (2) the 15-sec running mean. In addition, the standard deviations corresponding to each average were computed.

The 20-sec running mean was computed every 20 sec by summing the values of the parameter during the previous 20 sec and dividing by the number of values. In mathematical terms,

$$Q = \frac{1}{N} \sum_{k=o}^{N-1} P_{n-k}$$

where Q is the desired mean, $P_j$ is the value of the parameter at a particular sample instant denoted by j, N is the number of samples in 20 sec, and $P_n$ is the value of the parameter at the end of the averaging interval.

The 20-sec standard deviation was computed by the following method:

$$\sigma^2 = \frac{1}{N} \sum_{k=o}^{N-1} (Q - P_{n-k})^2$$

where $\sigma$ is the desired standard deviation.

The running mean R is defined for every data point. The defining equation is as follows:

$$R_n = (1 - a) \sum_{k=o}^{\infty} a^k P_{n-k}$$

This equation is not practical for implementation with a digital computer, due to necessary storing of all the separate values $P_j$. Instead, an equivalent recursive formula is used, as follows:

$$R_n = a R_{n-1} + (1 - a) P_n$$

The numerical value of a, used in the present work, was

$$a = 15/16$$

Similarly, the running mean square can be defined as follows:

$$Z_n^2 = a Z_{n-1}^2 + (1 - a) P_n^2$$

The running standard deviation $S_n$ is defined thus:

$$S_n = (Z_n^2 - R_n^2)^{1/2}$$

For each of the ten parameters, the quantities Q and $\sigma$ were computed and tabulated for 20-sec intervals. In addition, the quantities $R_n$ and $S_n$ were computed and tabulated for each ECG pulse time.

## AUDIO TONE RESPONSE

A different type of analysis was used to detect a possible trend or correlation of the subject's response to the audio stimulus tone. The desired end result of this analysis is a plot of the composite or average of a given physiological parameter, showing how the parameter is affected, on the average, by the tone.

A computer routine was devised to sort through the data and to store each sequence of a given parameter during a time interval extending from 5 sec before to 20 sec after the beginning of each audio stimulus. These values for a given subject and test day were stored according to the following set of test conditions:

Game duration:  80 or 120 sec

Game type:  1, 2, or 3

Response mode:  Ignore or turn off

Decibel level:  90, 100, 110, or 120 db

Thus, for each subject and test day, there were 48 separate sets of conditions for each of the ten parameters.

To generate a composite plot of a given parameter for one of the 48 sets of conditions, the available plot data for all test subjects were averaged. These averages were plotted as functions of time on a time scale running from -5 to +20 sec and referred to the beginning of the audio stimulus tone.

Typical outputs of this data reduction and analysis method are shown in the following two figures that present data for ECG and HPG-ECG parameters, respectively.

6-4

PSYCHOLOGICAL ASSESSMENT

LEON SCHIPPERS    SUBJECT 8   TEST DAT 1

ECG

| G | R1 | R2 | TIME (SEC) | AUDIO LEVEL | AUDIO RESP | INST | RUN MEAN | RUN SD | INST AMP | RUN MN AMP | RUN SD AMP | 20 SEC MEAN | 20 SEC SD | INST CH HRT | RUN MN CH HRT | HB |
|---|----|----|------------|-------------|------------|------|----------|--------|----------|------------|------------|-------------|-----------|-------------|---------------|----|
| 1 | 33 | 10 | 261.374 | 0.0 | 0 | 87.46 | 94.79 | 3.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -3.860 | -0.488 | 151 |
| 1 | 33 | 10 | 262.058 | 0.0 | 0 | 87.71 | 94.34 | 3.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.255 | -0.441 | 152 |
| 1 | 33 | 10 | 262.732 | 0.0 | 0 | 89.02 | 94.01 | 3.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.301 | -0.332 | 153 |
| 1 | 33 | 10 | 263.392 | 0.0 | 0 | 90.90 | 93.82 | 3.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.888 | -0.194 | 154 |
| 1 | 33 | 10 | 264.047 | 0.0 | 0 | 91.60 | 93.68 | 3.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.693 | -0.138 | 155 |
| 1 | 33 | 10 | 264.690 | 0.0 | 0 | 93.31 | 93.66 | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.709 | -0.023 | 156 |
| 1 | 33 | 10 | 265.324 | 0.0 | 0 | 94.63 | 93.72 | 3.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.324 | 0.061 | 157 |
| 1 | 33 | 10 | 265.944 | 0.0 | 0 | 96.77 | 93.91 | 3.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.136 | 0.190 | 158 |
| 1 | 33 | 10 | 266.571 | 0.0 | 0 | 95.69 | 94.02 | 3.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.080 | 0.111 | 159 |
| 1 | 33 | 10 | 267.199 | 0.0 | 0 | 95.54 | 94.11 | 3.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.152 | 0.094 | 160 |
| 1 | 33 | 10 | 267.838 | 0.0 | 0 | 93.89 | 94.10 | 3.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.644 | -0.013 | 161 |
| 1 | 33 | 10 | 268.485 | 0.0 | 0 | 92.73 | 94.01 | 3.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.161 | -0.085 | 162 |
| 1 | 33 | 10 | 269.135 | 0.0 | 0 | 92.30 | 93.91 | 2.96 | 0.00 | 0.00 | 0.00 | 94.37 | 3.08 | -0.428 | -0.106 | 163 |
| 1 | 33 | 10 | 269.795 | 0.0 | 0 | 90.90 | 93.72 | 2.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.398 | -0.187 | 164 |
| 1 | 33 | 10 | 270.454 | 0.0 | 0 | 91.04 | 93.55 | 2.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.137 | -0.167 | 165 |
| 1 | 33 | 10 | 271.118 | 0.0 | 0 | 90.36 | 93.35 | 2.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.685 | -0.199 | 166 |
| 1 | 33 | 10 | 271.772 | 90.0 | 78 | 91.74 | 93.25 | 2.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.381 | -0.100 | 167 |
| 1 | 33 | 10 | 272.421 | 0.0 | 0 | 92.44 | 93.20 | 2.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.706 | -0.050 | 168 |
| 1 | 33 | 10 | 273.060 | 0.0 | 0 | 93.89 | 93.24 | 2.71 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.446 | 0.043 | 169 |
| 1 | 33 | 10 | 273.619 | 0.0 | 0 | 107.33 | 94.12 | 4.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.437 | 0.880 | 170 |
| 1 | 33 | 10 | 274.311 | 0.0 | 0 | 86.70 | 93.66 | 4.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -20.629 | -0.464 | 171 |
| 1 | 33 | 10 | 274.921 | 0.0 | 0 | 98.36 | 93.95 | 4.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.655 | 0.293 | 172 |
| 1 | 33 | 10 | 275.538 | 0.0 | 0 | 97.24 | 94.16 | 4.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.115 | 0.205 | 173 |
| 1 | 33 | 10 | 276.165 | 0.0 | 0 | 95.69 | 94.25 | 4.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.550 | 0.095 | 174 |
| 1 | 33 | 10 | 276.800 | 0.0 | 0 | 94.48 | 94.27 | 4.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.205 | 0.014 | 175 |
| 1 | 33 | 10 | 277.446 | 0.0 | 0 | 92.87 | 94.18 | 4.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.608 | -0.087 | 176 |
| 1 | 33 | 10 | 278.094 | 0.0 | 0 | 92.59 | 94.08 | 3.97 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.286 | -0.099 | 177 |
| 1 | 33 | 10 | 278.753 | 0.0 | 0 | 91.04 | 93.89 | 3.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.545 | -0.190 | 178 |
| 1 | 33 | 10 | 279.413 | 0.0 | 0 | 90.90 | 93.71 | 3.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.137 | -0.186 | 179 |
| 1 | 33 | 10 | 280.082 | 0.0 | 0 | 89.68 | 93.45 | 3.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.222 | -0.251 | 180 |
| 1 | 33 | 10 | 280.747 | 0.0 | 0 | 90.22 | 93.25 | 3.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.539 | -0.202 | 181 |
| 1 | 33 | 10 | 281.413 | 0.0 | 0 | 90.09 | 93.05 | 3.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.135 | -0.197 | 182 |
| 1 | 33 | 10 | 282.070 | 0.0 | 0 | 91.32 | 92.95 | 3.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.234 | -0.108 | 183 |
| 1 | 33 | 10 | 282.727 | 0.0 | 0 | 91.32 | 92.84 | 3.58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | -0.101 | 184 |
| 1 | 33 | 10 | 283.382 | 0.0 | 0 | 91.60 | 92.77 | 3.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.278 | -0.077 | 185 |
| 1 | 33 | 10 | 284.028 | 0.0 | 0 | 92.87 | 92.77 | 3.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.276 | 0.006 | 186 |
| 1 | 33 | 10 | 284.677 | 0.0 | 0 | 92.44 | 92.75 | 3.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.429 | -0.020 | 187 |
| 1 | 33 | 10 | 285.324 | 0.0 | 0 | 92.73 | 92.75 | 3.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.285 | -0.001 | 188 |
| 1 | 33 | 10 | 285.974 | 0.0 | 0 | 92.30 | 92.72 | 3.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.428 | -0.028 | 189 |
| 1 | 33 | 10 | 286.616 | 0.0 | 0 | 93.45 | 92.77 | 2.97 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.150 | 0.045 | 190 |
| 1 | 33 | 10 | 287.260 | 0.0 | 0 | 93.16 | 92.79 | 2.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.290 | 0.024 | 191 |
| 1 | 33 | 10 | 287.910 | 0.0 | 0 | 92.30 | 92.76 | 2.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.860 | -0.030 | 192 |
| 1 | 33 | 10 | 288.568 | 0.0 | 0 | 91.18 | 92.66 | 2.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.122 | -0.098 | 193 |
| 1 | 33 | 10 | 289.217 | 0.0 | 0 | 92.44 | 92.65 | 2.64 | 0.00 | 0.00 | 0.00 | 92.73 | 3.43 | 1.264 | -0.013 | 194 |
| 1 | 33 | 10 | 289.861 | 0.0 | 0 | 93.16 | 92.68 | 2.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.717 | 0.032 | 195 |
| 1 | 33 | 10 | 290.512 | 0.0 | 0 | 92.16 | 92.65 | 2.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.001 | -0.032 | 196 |
| 1 | 33 | 10 | 291.160 | 0.0 | 0 | 92.59 | 92.65 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.426 | -0.003 | 197 |
| 0 | 0 | 0 | 291.811 | 0.0 | 0 | 92.16 | 92.62 | 2.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.426 | -0.030 | 198 |
| 0 | 0 | 0 | 292.455 | 0.0 | 0 | 93.16 | 92.65 | 2.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.001 | 0.034 | 199 |
| 0 | 0 | 0 | 293.094 | 0.0 | 0 | 93.89 | 92.73 | 2.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.729 | 0.077 | 200 |

Figure 6-1.   Psychological Assessment (ECG Parameters)

6-5

PSYCHOLOGICAL ASSESSMENT

LEON SCHIPPERS     SUBJECT 8   TEST DAT 1

HPG-ECG

| G | R1 | R2 | TIME (SEC) | AUDIO LEVEL | AUDIO RESP | INST | RUN MEAN | RUN SD | INST AMP | RUN MN AMP | RUN SD AMP | 20 SEC MEAN | 20 SEC SD | INST CH HRT | RUN MN CH HRT | HB |
|---|----|----|-----------|-------------|------------|------|----------|--------|----------|------------|------------|-------------|-----------|-------------|----------------|-----|
| 2 | 57 | 69 | 1132.085 | 0.0 | 0 | 229.00 | 232.34 | 3.60 | 10.51 | 10.96 | 0.82 | 0.00 | 0.00 | | | 1651 |
| 2 | 57 | 69 | 1132.650 | 0.0 | 0 | 231.00 | 232.25 | 3.50 | 10.07 | 10.91 | 0.83 | 0.00 | 0.00 | | | 1652 |
| 2 | 57 | 69 | 1133.217 | 0.0 | 0 | 235.00 | 232.42 | 3.45 | 10.27 | 10.87 | 0.81 | 0.00 | 0.00 | | | 1653 |
| 2 | 57 | 69 | 1133.794 | 0.0 | 0 | 235.00 | 232.58 | 3.40 | 11.05 | 10.88 | 0.79 | 0.00 | 0.00 | | | 1654 |
| 2 | 57 | 69 | 1134.395 | 0.0 | C | 241.00 | 233.11 | 3.87 | 12.11 | 10.95 | 0.82 | 0.00 | 0.00 | | | 1655 |
| 2 | 57 | 69 | 1135.005 | 0.0 | 0 | 235.00 | 233.23 | 3.78 | 11.10 | 10.96 | 0.79 | 0.00 | 0.00 | | | 1656 |
| 2 | 57 | 69 | 1135.641 | 0.0 | 0 | 244.00 | 233.90 | 4.49 | 12.62 | 11.07 | 0.87 | 0.00 | 0.00 | | | 1657 |
| 2 | 57 | 69 | 1136.264 | 0.0 | 0 | 247.00 | 234.72 | 5.38 | 12.39 | 11.15 | 0.90 | 0.00 | 0.00 | | | 1658 |
| 0 | 0 | 0 | 1136.905 | 0.0 | 0 | 229.00 | 234.36 | 5.39 | 12.10 | 11.21 | 0.90 | 0.00 | 0.00 | | | 1659 |
| 0 | 0 | 0 | 1137.531 | 0.0 | 0 | 229.00 | 234.03 | 5.38 | 11.38 | 11.22 | 0.87 | 0.00 | 0.00 | | | 1660 |
| 0 | 0 | 0 | 1138.157 | 0.0 | 0 | 222.00 | 233.27 | 5.97 | 10.70 | 11.19 | 0.85 | 0.00 | 0.00 | | | 1661 |
| 0 | 0 | 0 | 1138.767 | 0.0 | 0 | 222.00 | 232.57 | 6.39 | 10.52 | 11.15 | 0.84 | 0.00 | 0.00 | | | 1662 |
| 0 | 0 | 0 | 1139.362 | 0.0 | 0 | 207.00 | 230.97 | 8.75 | 7.61 | 10.92 | 1.18 | 0.00 | 0.00 | | | 1663 |
| 0 | 0 | 0 | 1139.957 | 0.0 | 0 | 223.00 | 230.47 | 8.69 | 9.19 | 10.82 | 1.22 | 0.00 | 0.00 | | | 1664 |
| 0 | 0 | 0 | 1140.525 | 0.0 | 0 | 219.00 | 229.79 | 8.86 | 15.86 | 11.13 | 1.69 | 231.47 | 7.06 | | | 1665 |
| 0 | 0 | 0 | 1141.078 | 0.0 | 0 | 226.00 | 229.52 | 8.63 | 10.40 | 11.09 | 1.65 | 0.00 | 0.00 | | | 1666 |
| 0 | 0 | 0 | 1141.616 | 0.0 | 0 | 234.00 | 229.80 | 8.42 | 12.14 | 11.15 | 1.62 | 0.00 | 0.00 | | | 1667 |
| 0 | 0 | 0 | 1142.155 | 0.0 | 0 | 242.00 | 230.56 | 8.67 | 13.24 | 11.28 | 1.64 | 0.00 | 0.00 | | | 1668 |
| 0 | 0 | 0 | 1142.696 | 0.0 | 0 | 240.00 | 231.15 | 8.70 | 13.34 | 11.41 | 1.67 | 0.00 | 0.00 | | | 1669 |
| 0 | 0 | 0 | 1143.236 | 0.0 | 0 | 245.00 | 232.02 | 9.07 | 12.78 | 11.50 | 1.65 | 0.00 | 0.00 | | | 1670 |
| 0 | 0 | 0 | 1143.797 | 0.0 | 0 | 241.00 | 232.58 | 9.04 | 13.68 | 11.63 | 1.68 | 0.00 | 0.00 | | | 1671 |
| 0 | 0 | 0 | 1144.391 | 0.0 | 0 | 233.00 | 232.60 | 8.76 | 12.90 | 11.71 | 1.66 | 0.00 | 0.00 | | | 1672 |
| 0 | 0 | 0 | 1145.039 | 0.0 | 0 | 235.00 | 232.75 | 8.50 | 12.86 | 11.78 | 1.63 | 0.00 | 0.00 | | | 1673 |
| 0 | 0 | 0 | 1145.709 | 0.0 | 0 | 237.00 | 233.02 | 8.29 | 13.47 | 11.89 | 1.63 | 0.03 | 0.00 | | | 1674 |
| 0 | 0 | 0 | 1146.392 | 0.0 | 0 | 242.00 | 233.58 | 8.32 | 14.03 | 12.02 | 1.66 | 0.00 | 0.00 | | | 1675 |
| 0 | 0 | 0 | 1147.092 | 0.0 | 0 | 244.00 | 234.23 | 8.44 | 14.48 | 12.18 | 1.71 | 0.00 | 0.00 | | | 1676 |
| 0 | 0 | 0 | 1147.791 | 0.0 | 0 | 239.00 | 234.53 | 8.25 | 14.17 | 12.30 | 1.73 | 0.00 | 0.00 | | | 1677 |
| 0 | 0 | 0 | 1148.481 | 0.0 | 0 | 236.00 | 234.62 | 8.00 | 13.78 | 12.39 | 1.71 | 0.00 | 0.00 | | | 1678 |
| 0 | 0 | 0 | 1149.132 | 0.0 | 0 | 235.00 | 234.64 | 7.75 | 10.88 | 12.30 | 1.69 | 0.00 | 0.00 | | | 1679 |
| 0 | 0 | 0 | 1149.767 | 0.0 | 0 | 228.00 | 234.23 | 7.67 | 10.51 | 12.19 | 1.70 | 0.00 | 0.00 | | | 1680 |
| 1 | 2 | 4 | 1150.384 | 0.0 | 0 | 228.00 | 233.84 | 7.58 | 10.38 | 12.07 | 1.70 | 0.00 | 0.00 | | | 1681 |
| 1 | 2 | 4 | 1151.003 | 0.0 | 0 | 227.00 | 233.41 | 7.52 | 10.47 | 11.97 | 1.69 | 0.00 | 0.00 | | | 1682 |
| 1 | 2 | 4 | 1151.615 | 0.0 | 0 | 229.00 | 233.13 | 7.36 | 10.34 | 11.87 | 1.68 | 0.00 | 0.00 | | | 1683 |
| 1 | 2 | 4 | 1152.228 | 0.0 | 0 | 232.00 | 233.06 | 7.14 | 10.73 | 11.80 | 1.65 | 0.00 | 0.00 | | | 1684 |
| 1 | 2 | 4 | 1152.832 | 0.0 | 0 | 236.00 | 233.25 | 6.95 | 12.26 | 11.83 | 1.60 | 0.00 | 0.00 | | | 1685 |
| 1 | 2 | 4 | 1153.434 | 0.0 | 0 | 240.00 | 233.67 | 6.92 | 13.36 | 11.93 | 1.60 | 0.00 | 0.00 | | | 1686 |
| 1 | 2 | 4 | 1154.043 | 0.0 | 0 | 232.00 | 233.56 | 6.71 | 13.23 | 12.01 | 1.58 | 0.00 | 0.00 | | | 1687 |
| 1 | 2 | 4 | 1154.665 | 0.0 | 0 | 235.00 | 233.65 | 6.51 | 13.16 | 12.08 | 1.55 | 0.00 | 0.00 | | | 1688 |
| 1 | 2 | 4 | 1155.300 | 0.0 | 0 | 229.00 | 233.36 | 6.40 | 12.26 | 12.09 | 1.50 | 0.00 | 0.00 | | | 1689 |
| 1 | 2 | 4 | 1155.932 | 0.0 | 0 | 227.00 | 232.96 | 6.39 | 10.51 | 11.99 | 1.50 | 0.00 | 0.00 | | | 1690 |
| 1 | 2 | 4 | 1156.559 | 0.0 | 0 | 222.00 | 232.28 | 6.73 | 10.01 | 11.87 | 1.53 | 0.00 | 0.00 | | | 1691 |
| 1 | 2 | 4 | 1157.184 | 0.0 | 0 | 223.00 | 231.70 | 6.89 | 10.58 | 11.79 | 1.52 | 0.00 | 0.00 | | | 1692 |
| 1 | 2 | 4 | 1157.804 | 0.0 | 0 | 232.00 | 231.72 | 6.68 | 11.46 | 11.77 | 1.47 | 0.00 | 0.00 | | | 1693 |
| 1 | 2 | 4 | 1158.426 | 0.0 | 0 | 239.00 | 232.17 | 6.70 | 12.65 | 11.82 | 1.44 | 0.00 | 0.00 | | | 1694 |
| 1 | 2 | 4 | 1159.038 | 0.0 | 0 | 237.00 | 232.47 | 6.59 | 20.15 | 12.34 | 2.45 | 0.00 | 0.00 | | | 1695 |
| 1 | 2 | 4 | 1159.644 | 0.0 | 0 | 235.00 | 232.63 | 6.41 | 12.98 | 12.38 | 2.38 | 0.00 | 0.00 | | | 1696 |
| 1 | 2 | 4 | 1160.251 | 0.0 | 0 | 233.00 | 232.65 | 6.21 | 12.64 | 12.40 | 2.30 | 0.00 | 0.00 | | | 1697 |
| 1 | 2 | 4 | 1160.868 | 0.0 | 0 | 230.00 | 232.49 | 6.05 | 12.17 | 12.38 | 2.23 | 234.03 | 5.84 | | | 1698 |
| 1 | 2 | 4 | 1161.486 | 0.0 | 0 | 230.00 | 232.33 | 5.88 | 11.71 | 12.34 | 2.16 | 0.00 | 0.00 | | | 1699 |
| 1 | 2 | 4 | 1162.116 | 0.0 | 0 | 228.00 | 232.06 | 5.79 | 11.04 | 12.26 | 2.12 | 0.00 | 0.00 | | | 1700 |

Figure 6-2.   Psychological Assessment (HPG-ECG Parameters)

## DATA AVERAGING

To determine normal human subject physiological response to a given set of test conditions under psychological assessment, it is necessary to calculate the arithmetic mean of responses for many test subjects. This task is performed by the psychological assessment merge (PSMER) program.

It was desired to observe the effect of audio tone interruptions on a subject's physiological functions as he played a game. To do this, PSMER produces plots of physiological parameters versus a time base of 5 sec before a tone, at the tone, and 20 sec after a tone, for various test conditions. There are ten different physiological parameters, as follows:

    ECG rate

    REG-ECG time

    REG amplitude

    FPG-ECG time

    FPG amplitude

    HPG-ECG time

    HPG amplitude

    REG-FPG time

    REG-HPG time

    FPG-HPG time

The test conditions are as follows:

    Two test days (test days 1 and 3)

    Four db levels (90, 100, 110, and 120)

    Three game types

    Two game times (80 and 120 sec)

    Two response modes:

        Mode 1--Subject responds by turning off tone.

        Mode 2--Subject ignores tone.

    NOTE:  PSMER merges the data for only one test day at a time.

## PROGRAM DESIGN

PSMER maintains two disk files for merging. File 1 contains 480 running sum records of the ten physiological parameters at various test conditions, each with 51 timesteps (half-second intervals for 5 sec before, at, and 20 sec after the occurrence of a tone). File 2 is structured with 480 records, as file one, but it contains the number of entries summed for each of the timesteps.

As the data comes off the digitized tape, it is expressed as the time of an event occurrence such as the ECG, REG, HPG, and FPG pulses, and the amplitude of the event (ECG pulse amplitude was not recorded). Also included on the tape are game level (game on or off), audio interrupt (indicates the occurrence of a tone), and audio tone level. This data must be matched with data from a Teletype printout that includes game type, game time, test day, response mode, and tone levels. The data from the Teletype printout is entered into the program via punched cards. The ten physiological parameters are computed in the case of a time parameter by a difference in the time of occurrence; in the case of amplitude parameters, they are computed by multiplication by a calibration factor. The computed data is based on the time of the ECG pulse occurrence; however, computed parameters based on equal half-second timesteps (in the 5 sec before, at, and 20 sec after tone occurrence arrangement) are required. Therefore, it is necessary to interpolate these values from the ECG-based data.

Basically, the program steps through the data, looking for the occurrence of a tone. When one is found, the program backsteps through the data to calculate and interpolate the ten parameters for ten timesteps. This calculates the parameters for the 5-sec-before-the-tone part of the plot. Then the program goes forward through the data to calculate and interpolate the ten parameters for the after-the-tone part of the plot. If another tone is encountered while calculating and interpolating, the program will stop stepping (forward or back) through the data because the new tone marks the start of a different test condition. When all calculation and interpolation has been completed for the tone, the ten parameters are added to their running sums in the appropriate file records. Also, the number of entries summed are kept in the other file.

To backstep through the data, it was necessary to maintain a buffer with enough data to calculate and interpolate 5-sec worth of parameters. This buffer had to be kept immediately behind the data being scanned for the tone occurrence.

The program starts by asking the operator, via the typewriter, if he is starting a new merge sequence or continuing a present one. If a new sequence is indicated, the program will zero-out both disk files. The program then prints the tape status request on the typewriter. At this point, the operator indicates through the data switches whether he is ready to process a tape of data, to halt the program for future continuation, or to jump to the program that plots the data. If a data tape is loaded, ready to be processed, and its associated data cards are loaded in the card reader, the operator answers the tape status request that he is ready to process. The program reads into the tape (from cards) the file numbers to be processed and also the parameter amplitude calibration factors. The program then positions the tape to the file it is to process. Information on the number of games to skip and to process is read from a card. The tape starts to be read and the backstep buffer is set up. Another line of data is read from the tape to see if a game is on, if it is one to be processed, or if no more games are to be processed. If no game is on or it is not to be processed, the backstep buffer is advanced and the last step repeated. If a game to be processed comes on, the game type,

game time, response mode, and tone levels for the game are read from cards.
The line of data is then checked for a tone. If a game to be processed is
already on, the program does not read in more game description cards, but
merely checks the line of data for a tone. If no tone is present, the backstep
buffer is advanced and the program jumps back to read another line of data.
If a tone was found, the ten parameters are computed at the tone. If for some
reason the data is bad for a calculation, data from neighboring time points are
used to interpolate a value.

Next, the backstep buffer is used to calculate the ten parameters for
5 sec before tone occurrence. If bad data is encountered, a zero is calculated
for the particular parameter at the time point. The interpolation routine will
spot the zero and not use it for interpolation. The interpolation routine will
now calculate the ten parameters in 1/2-sec intervals for 5 sec before tone
occurrence. If a previous tone is encountered in the interpolation process,
the process will stop and the program will proceed to calculate the parameters
for 20 sec after tone occurrence. The backstep buffer is advanced and another
line of data is read from the tape. If a tone is present in the new line of
data, the program jumps to the forward buffer interpolation routine. If not,
the parameters are calculated for the present line of data and stored in a
forward buffer.

The program continues the read process until either enough data for inter-
polating a full 20-sec worth of half-second timesteps is in the forward buffer,
or a tone is encountered in a line of data. At this time, the interpolation
routine will calculate the parameters in half-second intervals for either a full
20 sec or as far as possible if a tone cuts short the forward buffer. All of
the preceding calculated data is added to the disk. The game type, response
mode, and game time information read from cards, and the db level of the pro-
cessed tone determine the set of ten file records (one record per parameter) to
which the data is added. The new data is added to that on the disk to maintain
a running sum. The same file record number on file 2 contains the number of
entries summed, and it is incremented to reflect the summation of the new data.

After the data is entered on disk, the program goes back to read another
line of data, check on game status, and look for a tone. If all the games that
were specified have been processed, or if there are no more games in the file,
the program jumps back to the tape positioning routine to advance to the next
file. If all the files for a given tape have been processed, or an end of
tape was encountered, the tape will rewind to load point. The program then
goes to the tape status request. When all the tapes in the merge sequence have
been processed, the operator tells the program to jump to the plot routine.

The plot program uses the information in file 1 (data summed) and file 2
(number of entries summed) to calculate the arithmetic mean of each timestep
for the ten parameters at various conditions. The program then writes a mag-
netic tape with the plot images for later use by a program called WTRPL. WTRPL
uses the plot image to run the Calcomp plotter. The plots are arranged by
parameter versus time. The time axis runs from -5.00 sec (5 sec before the tone)
to 20.00 sec (20 sec after the tone).

6-8

## Input Format

The input to PSMER consists of magnetic tape on drive zero (nine-track) and punched cards. The data on the cards must be matched with that on the tape. This matching primarily consists of assigning game test conditions from the Teletype printout to the games on the tape, and tone levels (db) from the Teletype printout to the audio interrupts. The data card format for PSMER is shown in Table 6-1. If the plot routine (TPL) is entered directly from PSMER, its data cards must be behind the last PSMER data deck. TPL's data cards have the plot titles on them and they are not to be changed except for the last one. The last data card is used to specify which test conditions one does not wish to plot. One type of each test condition may be eliminated. The format is as follows:

| Card Column | Type | Description |
|---|---|---|
| 1 - 5 | I | Game time (0 for 80 sec, 240 for 120 sec) |
| 6 - 10 | I | Response mode (1 or 2) |
| 11 - 15 | I | Decibel level (1 for 90, 2 for 100, 3 for 110, 4 for 120) |
| 16 - 20 | I | Game type (1, 2, or 3) |

To retain a condition, simply enter a nonvalid number in its field (example: entering a zero in the response mode field says plot for both modes).

## Digitized Magnetic Tape Format

The digitized tape used by PSMER is arranged in a 480-word physical record that is divided into 20 logical records, with each logical record containing the data at an ECG pulse. There are 24 words per logical record, as follows:

| | | | |
|---|---|---|---|
| 1. | ECG time (MSB) | 13. | HPG time (MSB) |
| 2. | ECG time (LSB) | 14. | HPG time (LSB) |
| 3. | ECG amplitude (no meaning) | 15. | HPG amplitude |
| 4. | Spare | 16. | Spare |
| 5. | REG time (MSB) | 17. | Audio interrupt |
| 6. | REG time (LSB) | 18. | Game level |
| 7. | REG amplitude | 19. | Audio level |
| 8. | Spare | 20. | Spare |
| 9. | FPG time (MSB) | 21. | Spare |
| 10. | FPG time (LSB) | 22. | Spare |
| 11. | FPG amplitude | 23. | Spare |
| 12. | Spare | 24. | Spare |

This format easily lends itself to a four-by-six array with ECG = 1, REG = 2, FPG = 3, etc.

TABLE 6-1

PSMER DATA CARD FORMAT

| Card No. | Card Column | Type | Comments |
|----------|-------------|------|----------|
| 1 | 1 - 5 | I | File numbers to be read |
|  | 6 - 10 | I | File numbers to be read |
|  | 6 - 10 | I | Terminate numbers with a zero |
|  | 76 - 80 | I | Terminate numbers with a zero |
| 2 | 1 - 5 | F | Calibration amplitude ECG |
|  | 6 - 10 | F | Calibration amplitude REG |
|  | 11 - 15 | F | Calibration amplitude FPG |
|  | 16 - 20 | F | Calibration amplitude HPG |
| 3 | 1 - 5 | I | Number of games to skip |
|  | 6 - 10 | I | Number of games to process |
| 4 | 1 - 5 | I | Game type |
|  | 6 - 10 | I | Response mode type |
|  | 11 - 15 | I | Game time |
| 5 | 1 - 5 | I | Tone levels |
|  | 6 - 10 | I | Tone levels |
|  | 6 - 10 |  |  |
|  | 6 - 10 |  |  |
|  | 76 - 80 | I | Tone levels |

NOTES:  Cards 1 and 2 are repeated for every tape.

Card 3 is repeated for every file read.

Cards 4 and 5 are repeated for every game processed.

## Output

PSMER produces a magnetic tape, with plot information as output. When used as data by WTRPL, this tape produces a series of plots on the Calcomp plotter. The abcissa is the time axis, in seconds, and the ordinate is the parameter axis. The upper left portion of the plot contains the name of the parameter plotted, game type, game time, and response mode. Figures 6-3 and 6-4 show typical plots generated by this program.

## AUDMP Program

Occasionally, the Teletype printout data does not correspond exactly to the data on the tape. This usually is due to noise readings on the tape. Sometimes there are more tones in a game on the tape than indicated by the Teletype printout data. Also, there may be more games on the tape than indicated on the printout data. To aid in the reconciliation of these differences, the AUDMP program prints out the games and audio interrupts found in each file on the tape. Any extra tones found on the tape can be taken care of by putting a zero, for its level, on the tone-level card. PSMER ignores any tone assigned a zero level. Extra games can be taken care of by assigning them a game time of 100 on the game information card. PSMER ignores any game with a time of 100.

AUDMP data card setup is as follows:

| Column | Description |
|--------|-------------|
| 1 - 8  | Tape number (left justified) |
| 9 - 11 | Number of files on tape (I format, right justified) |
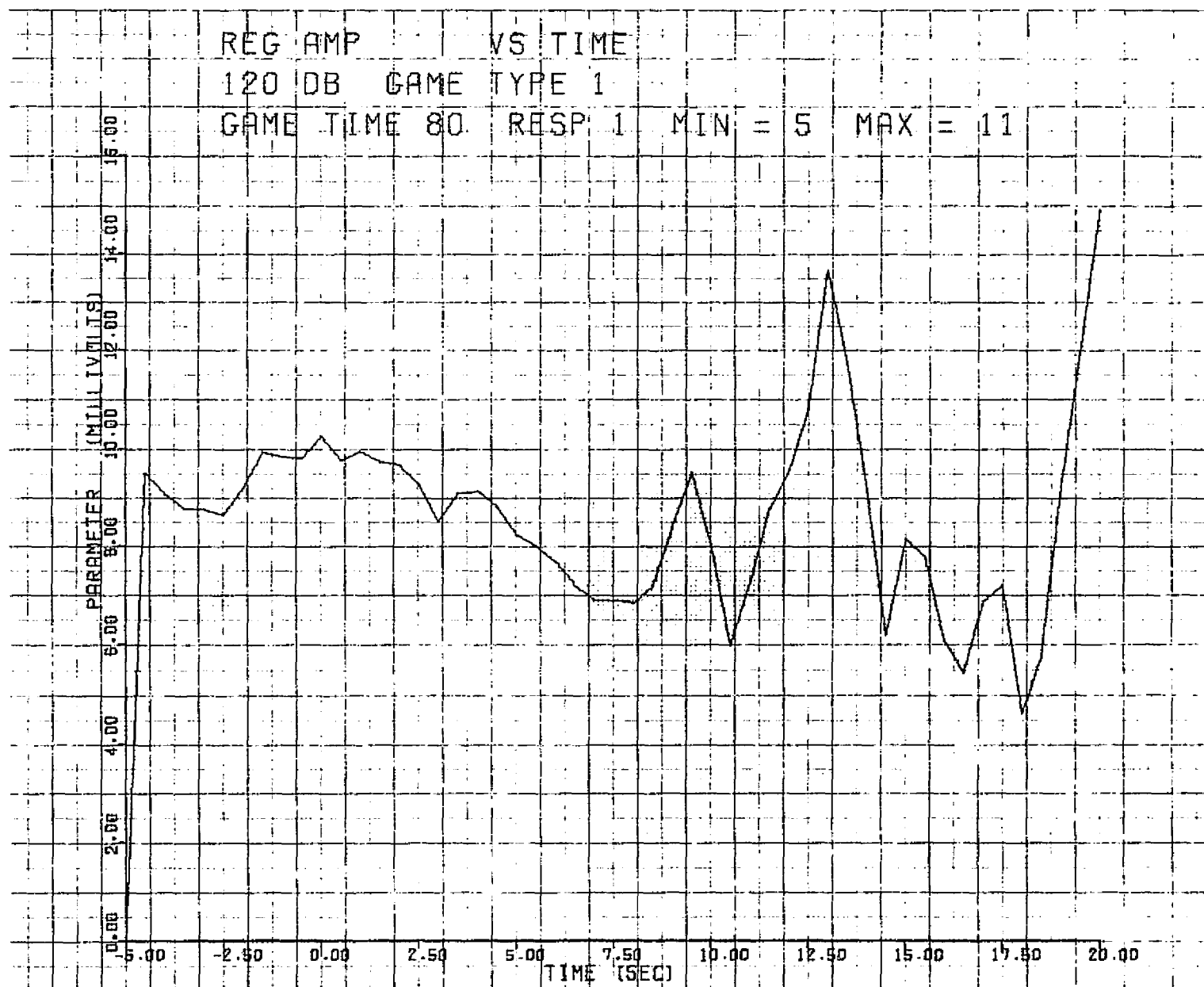
Figure 6-3. PSMER Output (REG Amplitude versus Time)
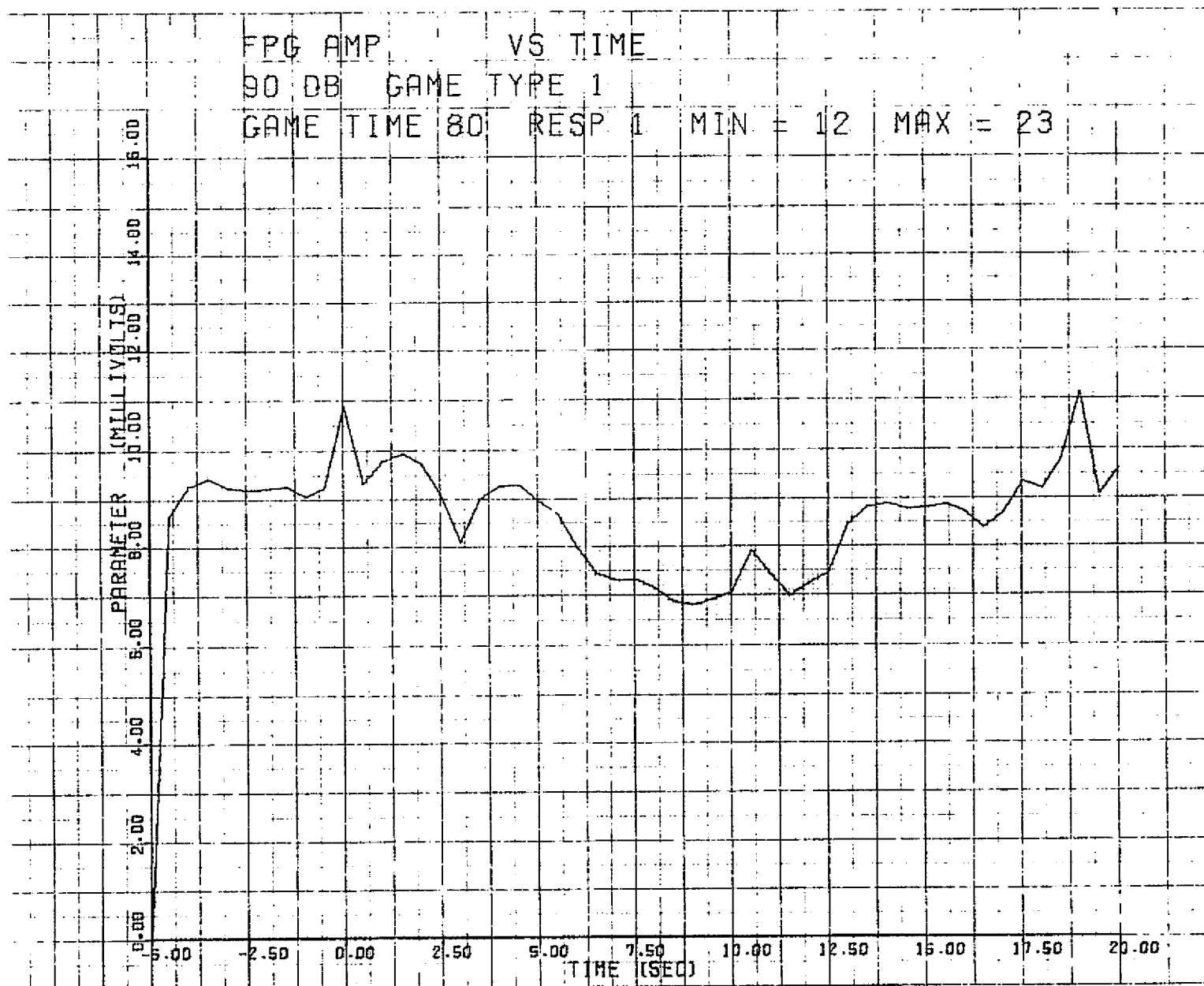
Figure 6-4. PSMER Output (FPG Amplitude versus Time)

# SECTION VII

## RESULTS

The results of this experiment are presented in three major subsections that report on reaction time, visual matrix (VM) game performance, and the physiological dependent variables, respectively. Periodic reference to the experimental design (Figure 3-1) will be of assistance.

### PERFORMANCE DATA

### Reaction Time

The reaction times of the subjects in response to the auditory probe stimulus were measured to the nearest 0.001 sec. Reaction time data tends to be skewed toward longer time intervals, principally because of infrequent, long periods in which the auditory signal is not detected. This is especially true for the 90-db auditory probe in this experiment. Consequently, for the purposes of statistical testing, a logarithmic transformation was performed on the reaction time data. All statistical testing was performed with log (RT x 1000).

Figures 7-1 and 7-2 present the mean reaction times as a function of the intensity of the auditory probe stimulus for the first and third days of testing, respectively. These curves illustrate the difficulty that the subjects had in detecting the 90-db tone on the first day of testing, the decrease in reaction time as the probe stimulus intensity increased, and the interactive effects of task duration and probe stimulus intensity. Reaction times also are influenced by the type of VM task. It is apparent that the reaction time is much faster for task type I than for tasks II and III. This observation corresponds to the performance data in the next subsection, where VM task II is shown to be more difficult than tasks I or III, and task III is demonstrated to be more difficult than task I.

Figure 7-3 is a comparison of reaction time data between test conditions that do not include performance of the VM task and test conditions including the VM task. As seen from the figure, the reaction time for conditions with both reaction time and VM tasks is considerably slower than for test conditions where reaction time is the only task. The effect of the inclusion of the VM task is an ≈37 percent increase in reaction time. The same observation was made for the first test day, as seen in Figure 7-4. This figure also illustrates the change in reaction time as learning takes place.

Analysis of variance treatment of the reaction time data is presented in Tables 7-1, 7-2, and 7-3. A review of these tables indicates that each of the independent variables (days training, auditory probe intensity, inclusion/exclusion of the VM task, type of VM task, and the time allowed for the VM task) have a statistically significant effect on reaction time. In addition, statistically significant secondary interactive effects are identified between auditory probe intensity and the type of VM task, and between the type of task and the amount of training. The only significant triple-order interaction is
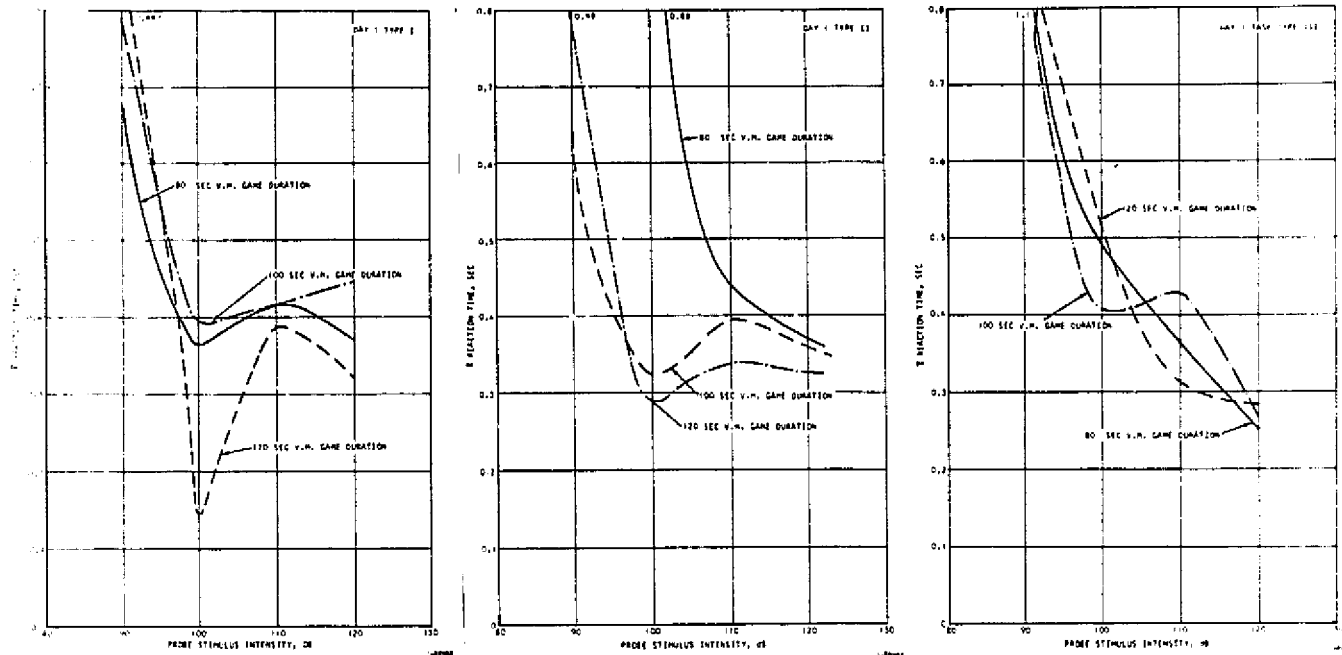
Figure 7-1. Test Day 1--Mean Reaction Time as a Function of
Auditory Probe Intensity and VM Task Duration
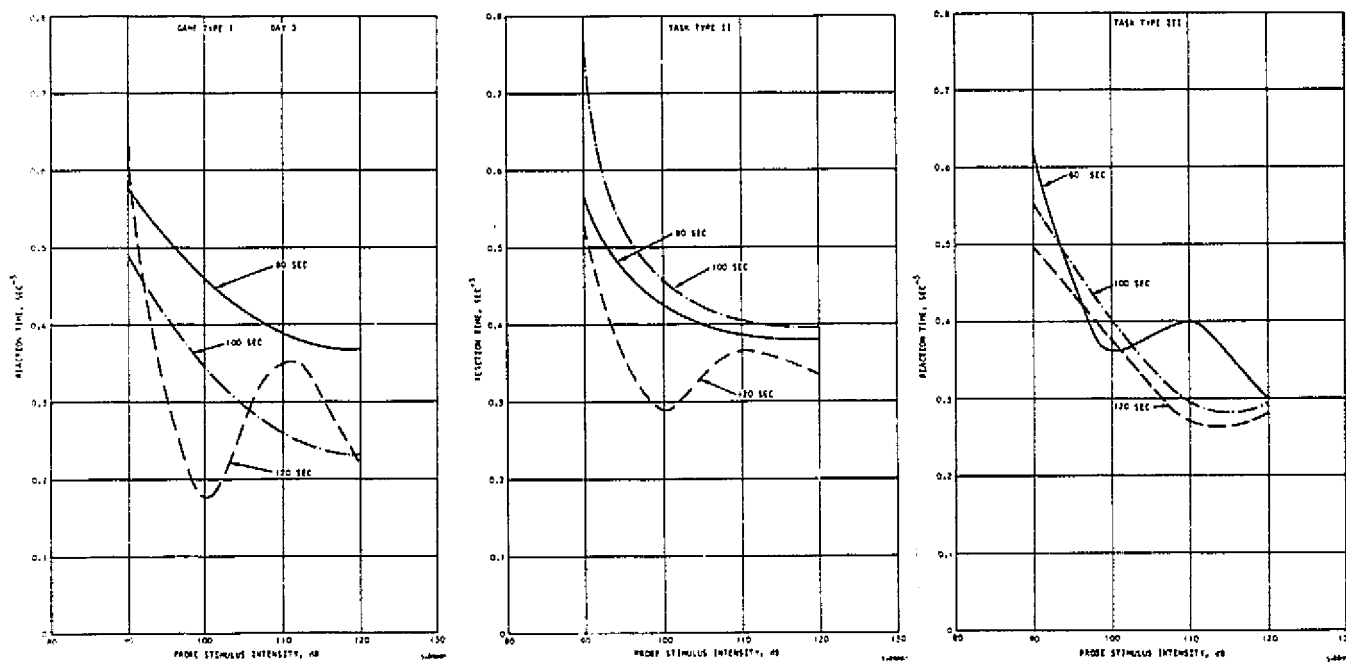


Figure 7-2. Test Day 3--Mean Reaction Time as a Function of
Auditory Probe Intensity and VM Task Duration

7-2
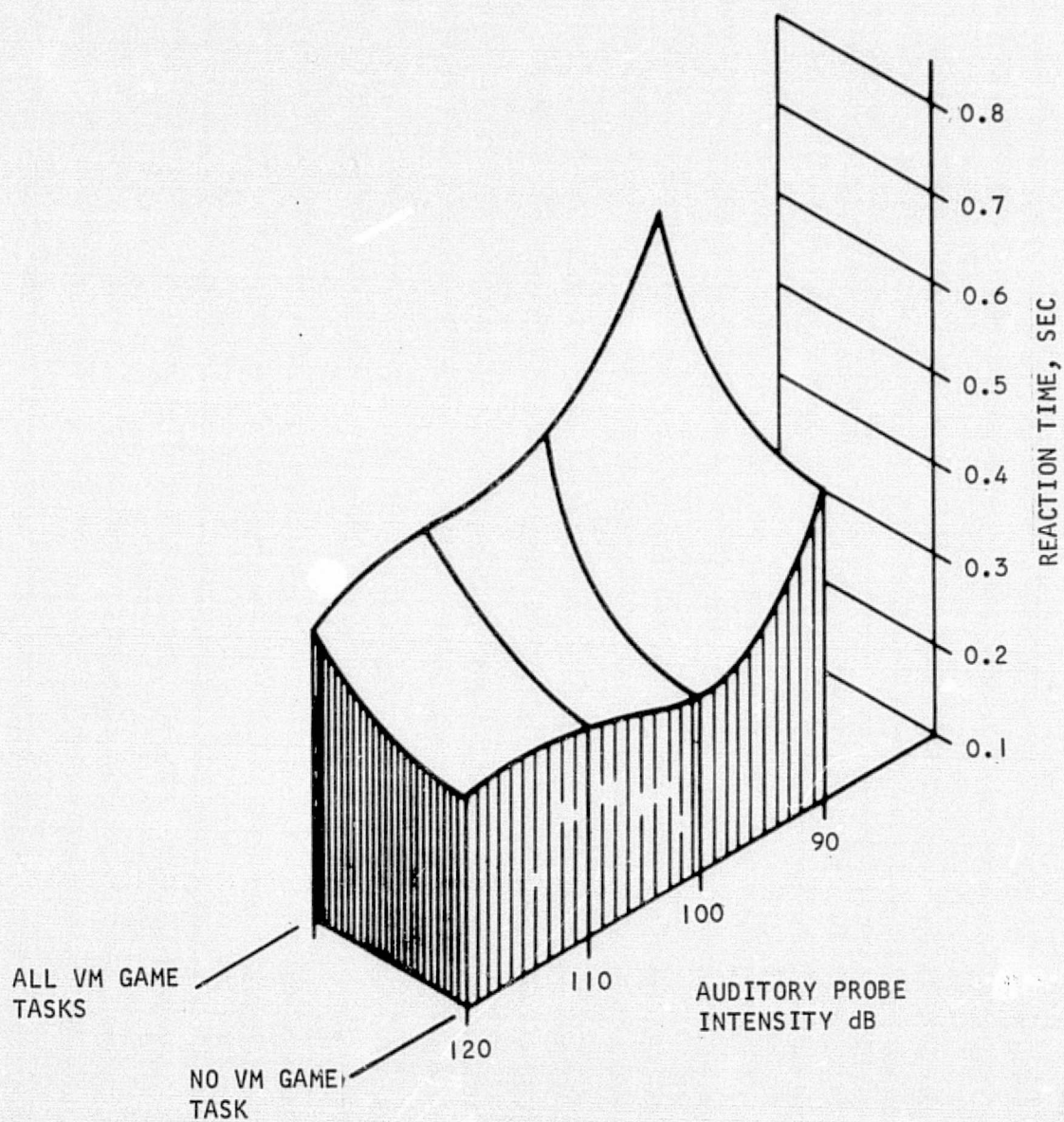
Figure 7-3.   Effect of VM Task on Reaction Time for Test Day 3
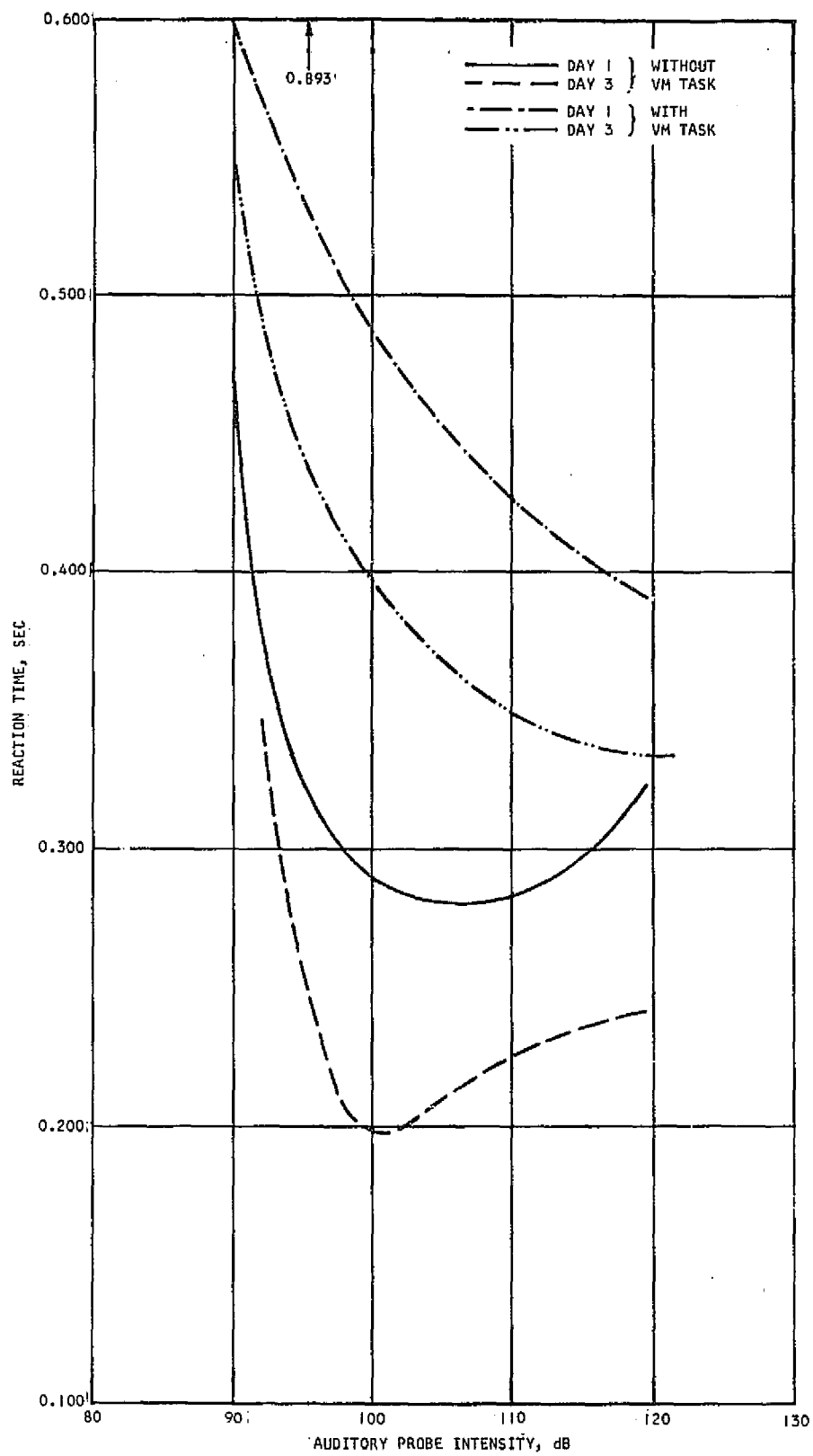
S-88997

Figure 7-4.  Effects of Learning on Reaction Time Task
With and Without VM Task

TABLE 7-1

ANOVA REACTION TIME--
DAYS X AUDITORY PROBE INTENSITY

| Number of Variables 2 | | | | | |
|---|---|---|---|---|---|
| Number of Replicates 18 | | | | | |
| Variable | No. of Levels | | Description | | |
| 1 | 2 | | Day 1 versus Day 3 | | |
| 2 | 4 | | Auditory Probe Intensity | | |
| Grand Mean 2.66192 | | | | | |
| Source of Variation | Degrees of Freedom | Sums of Squares | Mean Squares | F | Sig |
| 1 | 1 | 0.42806 | 0.42806 | 27.89 | <0.001 |
| 2 | 3 | 1.94983 | 0.64994 | 42.34 | <0.001 |
| 12 | 3 | 0.11355 | 0.03785 | 2.46 | <0.01 |
| Within Replicates | 136 | 2.08808 | 0.01535 | | |
| Total | 143 | 4.57951 | | | |

## TABLE 7-2

### ANOVA REACTION TIME--
### DAYS X AUDITORY PROBE STIMULUS
### X VM TASK/NO VM TASK

Number of Variables    3

Number of Replicates   16

| Variable | No. of Levels | Description |
|----------|---------------|-------------|
| 1 | 2 | Condition 3 versus Condition 6 |
| 2 | 2 | Day 1 versus Day 3 |
| 3 | 4 | Auditory Probe Intensity |

Grand Mean   2.55734

| Source of Variation | Degrees of Freedom | Sums of Squares | Mean Squares | F | Sig |
|---------------------|--------------------|-----------------|--------------|------|-------|
| 1 | 1 | 2.34789 | 2.34789 | 53.02 | <0.001 |
| 2 | 1 | 0.92785 | 0.92785 | 20.96 | <0.001 |
| 3 | 3 | 2.56695 | 0.85565 | 19.32 | <0.001 |
| 12 | 1 | 0.00693 | 0.00693 | 0.16 | NS |
| 13 | 3 | 0.25091 | 0.08364 | 1.89 | NS |
| 23 | 3 | 0.11014 | 0.03671 | 0.83 | NS |
| 123 | 3 | 0.05747 | 0.01916 | 0.43 | NS |
| Within Replicates | 240 | 10.62836 | 0.04428 | | |
| Total | 255 | 16.89648 | | | |

# TABLE 7-3

## ANOVA REACTION TIME--
## DAYS X TASK DURATION X TASK TYPE
## X AUDITORY PROBE INTENSITY

| Number of Variables 4 | | | | | |
|---|---|---|---|---|---|
| Number of Replicates 18 | | | | | |

| Variable | No. of Levels | Description | | | |
|---|---|---|---|---|---|
| 1 | 2 | Day 1 versus Day 3 | | | |
| 2 | 3 | Task Duration | | | |
| 3 | 3 | Task Type | | | |
| 4 | 4 | Auditory Probe Intensity | | | |

| Grand Mean 2.61966 | | | | | |
|---|---|---|---|---|---|

| Source of Variation | Degrees of Freedom | Sums of Squares | Mean Squares | F Ratio | Sig |
|---|---|---|---|---|---|
| 1 | 1 | 1.97152 | 1.97152 | 12.9955 | <0.001 |
| 2 | 2 | 2.01664 | 1.00832 | 6.6464 | <0.005 |
| 3 | 2 | 1.14742 | 0.57371 | 3.7817 | <0.025 |
| 4 | 3 | 22.28683 | 7.42894 | 48.9687 | <0.001 |
| 12 | 2 | 0.01491 | 0.00745 | 0.0491 | NS |
| 13 | 2 | 0.05974 | 0.02987 | 0.1969 | NS |
| 14 | 3 | 0.92821 | 0.30940 | 2.0395 | NS |
| 23 | 4 | 0.36800 | 0.09200 | 0.6064 | NS |
| 24 | 6 | 1.81577 | 0.30263 | 1.9948 | NS |
| 34 | 6 | 2.76092 | 0.46015 | 3.0332 | <0.01 |
| 123 | 4 | 1.30613 | 0.32653 | 2.1524 | NS |
| 124 | 6 | 1.14320 | 0.19053 | 1.2559 | NS |
| 134 | 6 | 1.10929 | 0.18488 | 1.2187 | NS |
| 234 | 12 | 4.46755 | 0.37230 | 2.4540 | <0.005 |
| 1234 | 12 | 0.73476 | 0.06123 | | |
| Within Replicates | 1224 | 185.69058 | 0.15171 | | |
| Total | 1295 | 227.82140 | | | |

with task duration, task type, and auditory probe stimulus intensity. As a consequence of these analyses, we can have confidence that the effects of the independent variables on reaction time are as shown on the surfaces in Figures 7-5, 7-6, and 7-7.

## Visual Matrix Task

The performance on the VM task was determined by the difference between the subject's count of the items in the matrix and the actual number.

$$\text{Performance } \Delta \text{ percent} = \frac{\text{Subject's Count} - \text{Actual Count}}{\text{Actual Count}}$$

All visual matrix statistical calculations were done with performance Δ percent.

Figure 7-8 illustrates the improvement in performance across the three days of training. It can be seen from this figure that VM Task II is the most difficult task, and VM Task I is the easiest. This relationship was maintained across the training period and is simultaneously reflected in the reaction time data discussed earlier in this section.

Figure 7-9 illustrates the relationship between the time allowed for the VM task and VM performance Δ percent as a function of the task type for day 3. It is important to note that this relationship also tracks the reaction time data.

Table 7-4 presents the ANOVA treatment of the performance data. The ANOVA demonstrates the statistically significant effects of VM task type, task duration, and days training on VM task performance. A significant interaction was found between training and VM task type and between task type and duration. The lack of an effect of inclusion of the reaction time task on the VM task performance is surprising. This may indicate that reaction time is a more sensitive indicator of task demand contingencies than VM task performance.
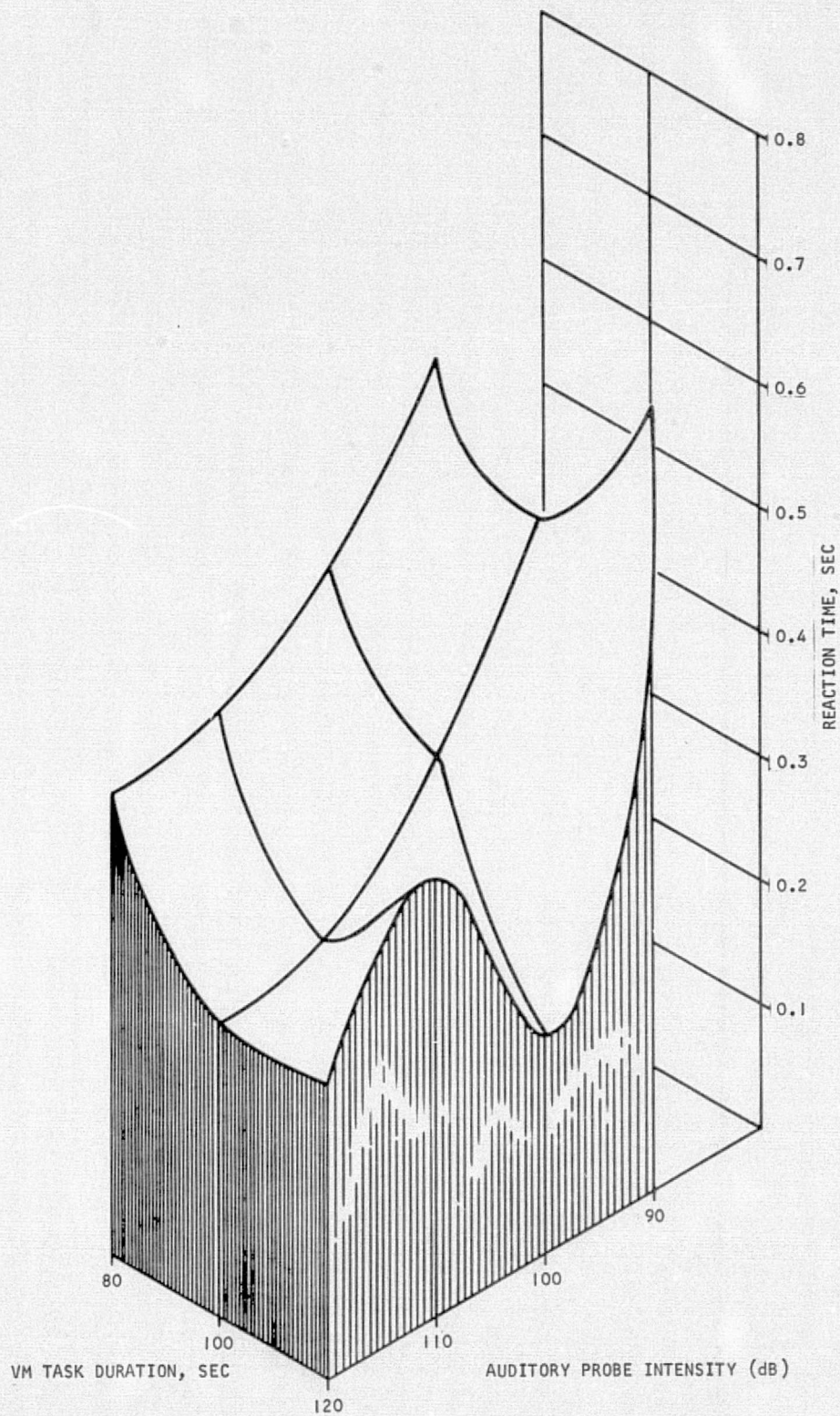
Figure 7-5. Reaction Time as a Function of VM Task Duration and Auditory Probe Intensity for VM Task 1
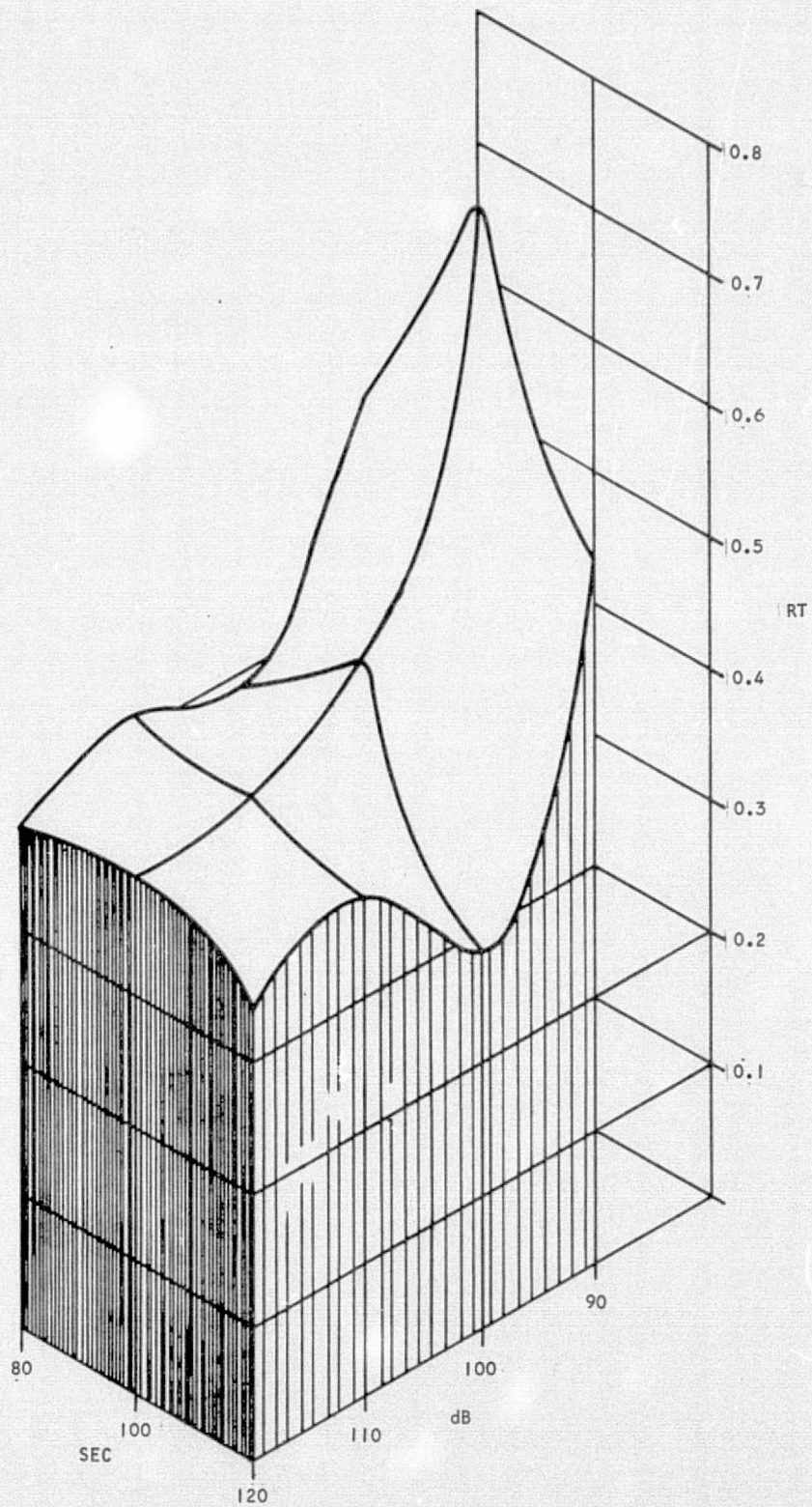
Figure 7-6. Reaction Time as a Function of VM Task Duration
and Auditory Probe Intensity for VM Task II
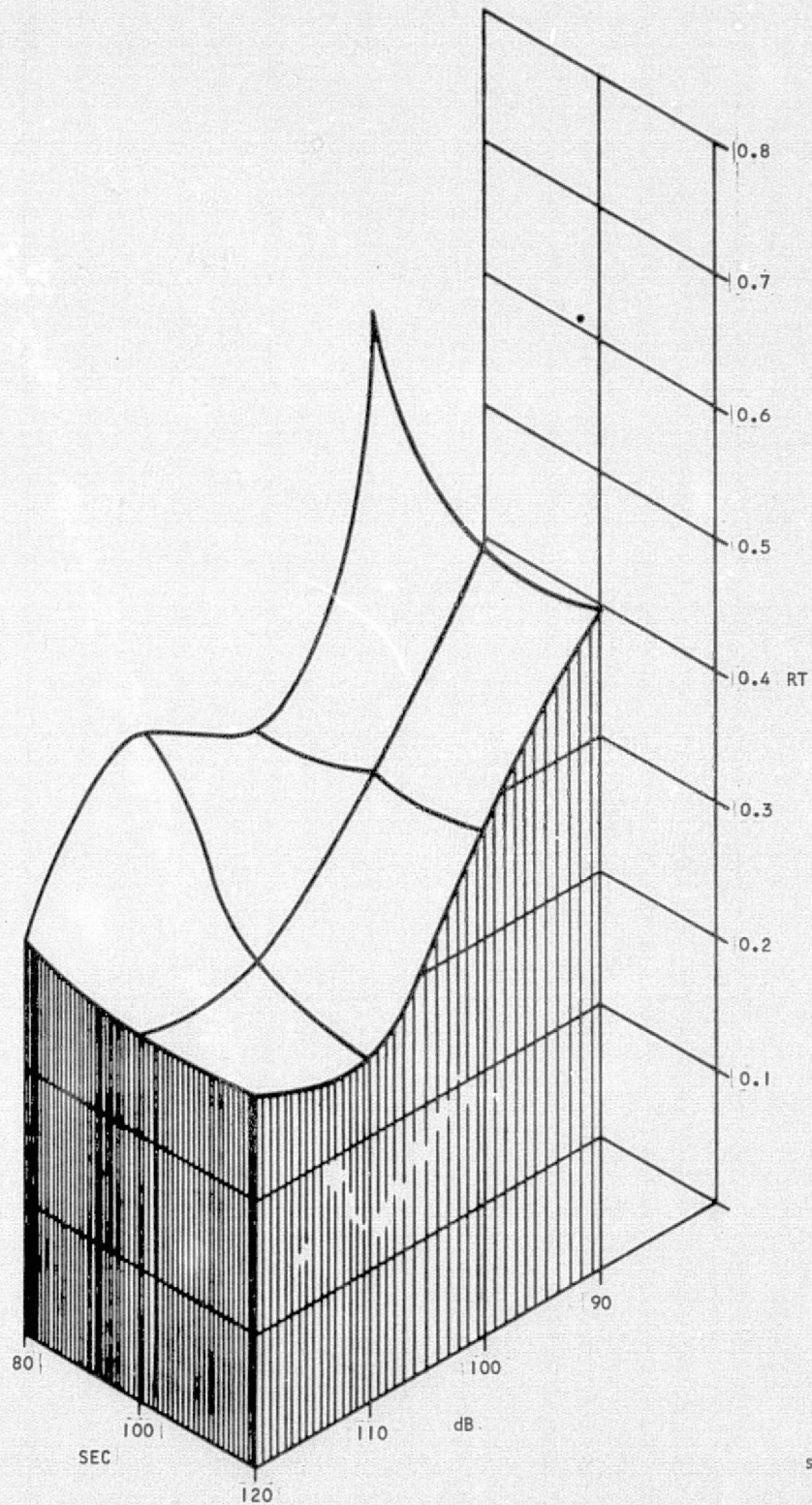
S-88993

Figure 7-7. Reaction Time as a Function of VM Task Duration
and Auditory Probe Intensity for VM Task III
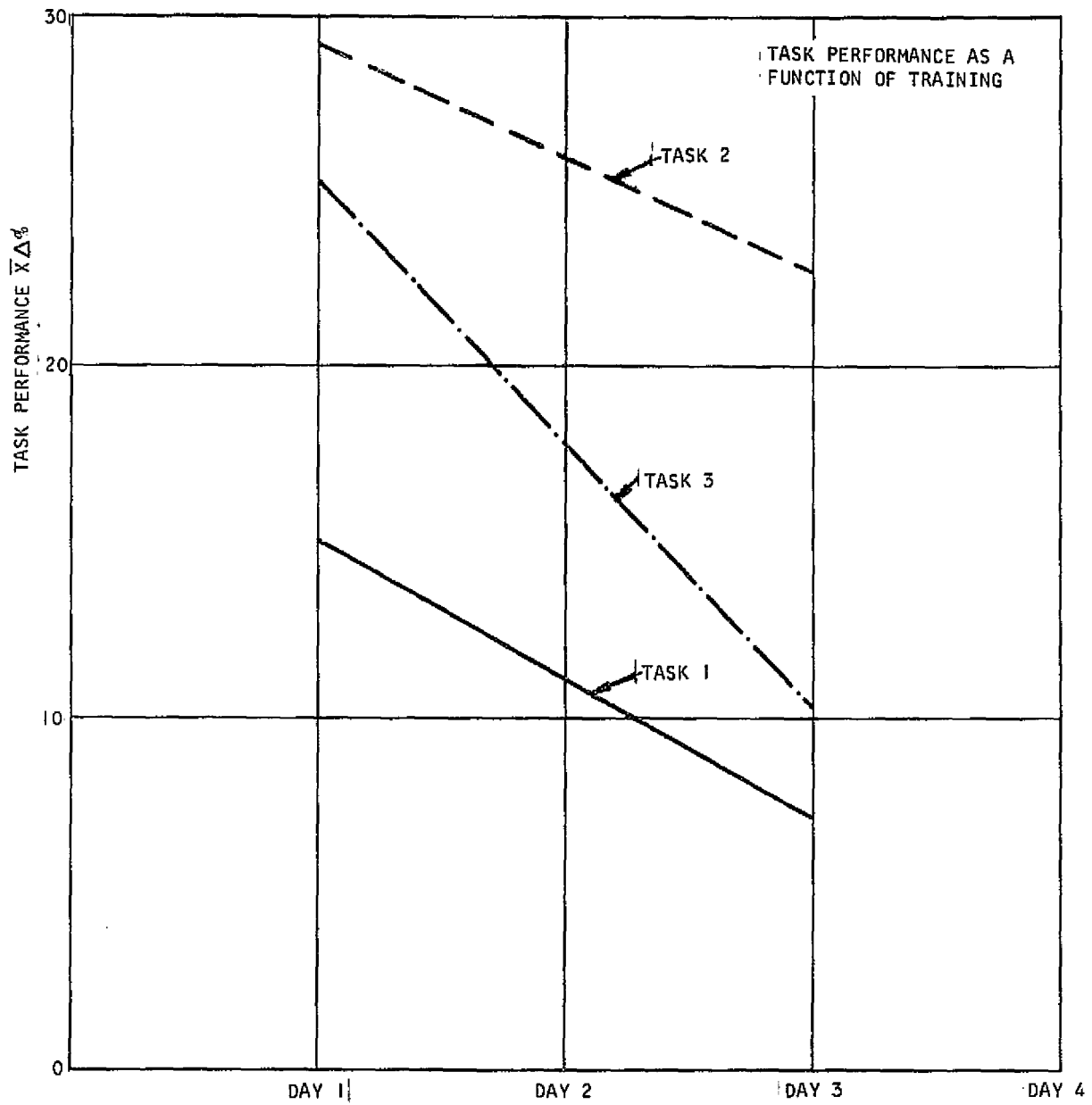
Figure 7-8.  Task Performance as a Function of Training
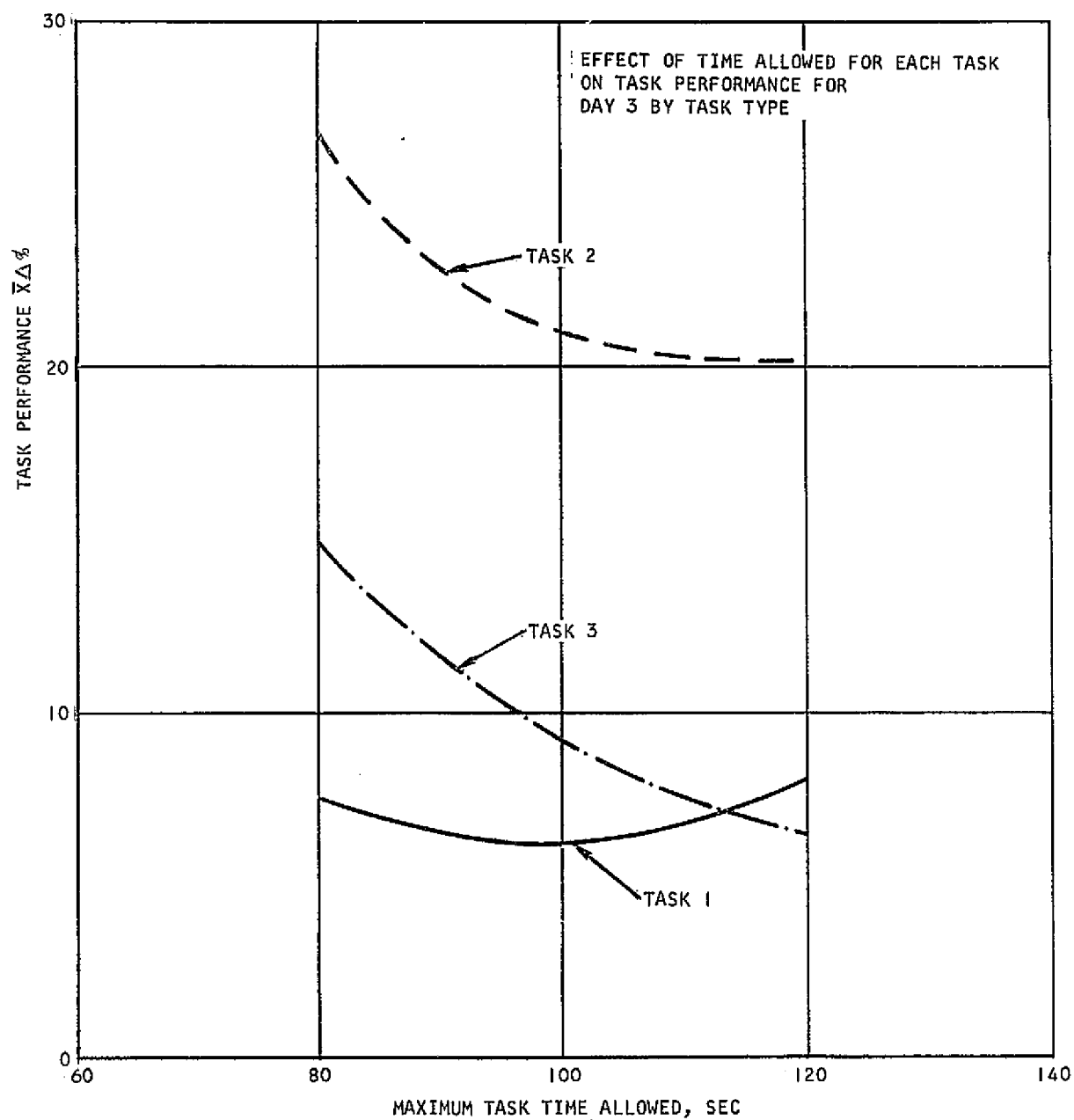
Figure 7-9.  Effect of Time Allowed for Each Task on
Task Performance for Day 3, by Task-Type

TABLE 7-4

ANOVA TASK PERFORMANCE Δ PERCENT
TASK DURATION X TASK TYPE X CONDITION 5
VERSUS CONDITION 6 X DAYS TRAINING

| Number of Variables | 4 | |
|---|---|---|
| Number of Replicates | 18 | |

| Variable | No. of Levels | Description |
|---|---|---|
| 1 | 2 | Day 1 versus Day 3 |
| 2 | 2 | Condition 5 versus Condition 6 |
| 3 | 3 | Task Duration |
| 4 | 3 | Task Type |

| Grand Mean | 19.18773 | |
|---|---|---|

| Source of Variation | Degrees of Freedom | Sums of Squares | Mean Squares | F Ratio | Sig |
|---|---|---|---|---|---|
| 1 | 1 | 16950.50000 | 16950.50000 | 61.2829 | <0.001 |
| 2 | 1 | 20.50634 | 20.50633 | 0.0741 | NS |
| 3 | 2 | 3926.71781 | 1963.35889 | 7.0983 | <0.001 |
| 4 | 2 | 25432.13380 | 12716.06641 | 45.9737 | <0.001 |
| 12 | 1 | 48.22705 | 48.22705 | 0.1744 | NS |
| 13 | 2 | 149.77032 | 74.88516 | 0.2707 | NS |
| 14 | 2 | 5003.37427 | 2501.68701 | 9.0446 | <0.001 |
| 23 | 2 | 251.68462 | 125.84230 | 0.4550 | NS |
| 24 | 2 | 711.20795 | 355.60376 | 1.2857 | NS |
| 34 | 4 | 4952.46294 | 1238.11572 | 4.4763 | <0.005 |
| 123 | 2 | 757.56881 | 378.78418 | 1.3695 | NS |
| 124 | 2 | 914.23621 | 457.11792 | 1.6527 | NS |
| 134 | 4 | 1034.31833 | 258.57935 | 0.9349 | NS |
| 234 | 4 | 92.69756 | 23.17438 | 0.0838 | NS |
| 1234 | 4 | 342.67969 | 85.66992 | | |
| Within Replicates | 612 | 169275.81250 | 276.59424 | | |
| Total | 647 | 229863.87500 | | | |

## PHYSIOLOGICAL PARAMETERS

The results presented in this section are the physiological parameters measured under test conditions 5 and 6 for test day 3 only. The data are presented in terms of the average analog signal. Data for 13 of the 18 subjects were found to be usable for this method of presentation. Each parameter is shown in analog form as a function of time for each of the experimental conditions. The data have been organized around the time of occurrence of the auditory probe stimulus; consequently, the abscissa of each plot commences at -5.0 sec. This is 5 sec before the presentation of the probe stimulus. The point at which the probe stimulus occurred is indicated as 0.00 time. Then the plots are continued for 12.5 sec following the probe stimulus. Data are shown for the 90-, 100-, and 120-db probe stimulus conditions. For reasons of economy and clarity of presentation, data for the 110-db probe stimulus, 100-sec VM performance task duration, and the VM task type III are not included in the plots. All plots are computed on a heart-beat-by-heart-beat basis. The symbols on the plot indicate line designations and are not data points. In the legends for these plots, the notation "Response 1" refers to conditions that require a reaction time response, while "Response 2" is the nonreaction time test conditions.

### Heart Rate

Figure 7-10* shows the averaged heart rate data for all the analyzed conditions. The average number of observations represented by any point or any line on this figure is 173. The minimum number of observations is 114. The maximum number of observations represented by any point is 266.

As seen from this figure, heart rates following the 100-db probe stimulus are faster than after the 90- or 120-db tones. Review of Figures 7-11 through 7-16 reveals that this observation is principally effective when the reaction time data (Figure 7-13) is separated from the nonreaction time data (Figure 7-14). This observation is of particular significance in light of the substantial improvement in performance represented by a reduction in reaction time following the 100-db stimulus in comparison with other intensities. The separation of heart rate (HR) by probe stimulus intensity for reaction time (RT) task is especially notable when compared to non-RT task conditions.

Comparison of Figure 7-15 with Figure 7-16 reveals that the average heart rates for the 80-sec game duration are slower than the 120-sec duration. This effect of game duration on heart rate is exacerbated by the RT task. In Figures 7-17 through 7-24, we can readily see this effect in VM Task I HR's, for heart rate is slower in Figure 7-17 than in Figure 7-18, while no HR difference exists between Figures 7-19 and 7-20. Again, with VM Task II-- Figures 7-21 to 7-24, HR is slower for the short game duration than the long durations, but only for situations involving reaction time.

It is most surprising that HR does not always show a response to the auditory probe stimulus. Figures 7-17, 7-18, and 7-22 are the best examples

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*Figures for this subsection are presented at the end of Section VII.

of the classical response of HR to the probe stimuli. These results do not show an orderly effect of probe stimulus intensity. Figures 7-17 and 7-22 are directly comparable, and both show higher HR's for the two higher intensities of the probe stimuli than the 90-db stimulus.

It is also apparent that HR is more variable in situations that include the RT task as compared with those without RT.

## Finger Plethysmograph Pulse Amplitude

Figure 7-25 presents the averaged values of all the finger plethysmograph (FPG) pulse amplitudes as a function of time. Figures 7-25 through 7-39 display this parameter as a fuction of the experimental conditions. The time sequence on the abscissa of each plot relates this parameter to the occurrence of the auditory probe stimulus event, time 0.00. Review of Figures 7-26 and 7-27 reveals no overall simple effect of VM game-type. Comparison of Figure 7-28 with Figure 7-29 clearly indicates that FPG amplitude is consistently lower for situations that involve an RT task than those with a non-RT situation. Furthermore, comparison of Figure 7-30 with Figure 7-31 reveals that FPG amplitude is consistently higher for the short (80-sec) VM task than when 120 sec was allowed.

Inspection of the more detailed plots for FPG amp, Figures 7-32 through 7-37, shows that the observations made above for both the RT and the VM task-duration independent variables are consistent. These plots also show that FPG amp is far more variable for the RT condition (Figures 7-32, 7-33, 7-36, and 7-37) than the non-RT condition (Figures 7-34, 7-35, 7-38, and 7-39).

It is also significant to observe that the lowest FPG amplitude values occur after the 100-db probe stimulus (Figure 7-33) and the 120-db probe stimulus (Figure 7-37). These low FPG amplitude values occur simultaneously with the most rapid RT responses (see Figure 7-2 ). Thus, the interaction of VM task type and duration appear in a correlated fashion for performance and physiological data.

## FPG-ECG Elapsed Time

This parameter is the elapsed time from the occurrence of the heartbeat (measured by the ECG) until the arrival of the pulse at the finger plethysmograph sensor. These time differences are presented in Figures 7-40 through 7-54.

Not much information was provided by this dependent variable, other than the observation that this $\Delta t$ is more variable for RT situations than non-RT situations (especially for 6 sec following the probe stimulus).

## Forehead Plethysmograph Pulse Amplitude

Figures 7-55 through 7-69 show plots of the amplitude of the forehead plethysmograph (HPG) signal as a function of time from the onset of the auditory probe stimulus (0.00 sec).

HPG amplitude is reduced during the more difficult VM task condition (VM task II) from the easier task (task I). Rela 've task difficulty is defined by VM task performance and RT performance.

As with many other dependent v ⁻ ⎴bles, HPG is more variable for RT than non-RT conditions.

Following the 120-db pulse amplitude, the HPG amplitude is substantially higher for the 80-sec VM task than for other db levels of VM durations.

### HPG-ECG Elapsed Time

This parameter is the elapsed time between the occurrence of a heartbeat and the arrival of the pulse at the forehead plethysmograph (see Figures 7-70 through 7-84).

The HPG pulse tends to occur faster after the ECG during the more difficult VM task conditions than the easier VM task (see Figures 7-71 and 7-72).

### Rheoencephalograph (REG) Amplitude

The REG signal pulse amplitude is shown in Figures 7-85 through 7-99. Inspection of the plots of REG as a function of time relative to the occurence of the probe stimulus reveals that REG pulse amplitude is lower with the more difficult VM task than the easy VM task. REG pulse amplitude is also lower for the RT task than the non-RT task.

### REG-ECG Elapsed Time

This parameter is the elapsed time between the ECG and the occurrence of the REG pulse (see Figures 7-100 through 7-114). Comparing Figure 7-101 with Figure 7-102, it is seen that the effect of the auditory probe stimulus separates by intensity, with the more difficult VM task. Figure 7-109 shows what appears to be an anomalous plot for the 90-db probe stimulus intensity. This apparently novel plot is similar to the HPG-ECG plot in Figure 7-78. Other data that correlate with this observation are a decrease in HPG amplitude for 90 db (Figure 7-63) and the lower HR for 90 db (Figure 7-18).

### REG-FPG Time Interval

This parameter is the difference between the time intervals of the ECG and the REG pulse period and the ECG to the FPG pulse period (see Figures 7-115 through 7-129). A negative value indicates that the REG pulse occurs prior to the FPG pulse in the interval between each heartbeat. Inspection of this parameter reveals that REG occurs prior to FPG. The temporal relationship between these two parameters is largely unaffected by the independent variables considered singly in Figures 7-115 through 7-121; however, under the more difficult test conditions (Figures 7-122 and 7-126), the parameter is substantially more variable than easier test conditions (Figures 7-124 and 7-125).

## REG-HPG Time Interval

This parameter is the difference between the time intervals of the ECG to the REG pulse period and the ECG to the HPG period (see Figures 7-130 through 7-144). Consequently, a positive value indicates that the HPG pulse occurs more quickly after the heartbeat than does the REG pulse. The data demonstrate that REG occurs prior to HPG. As expected, the relationship between HPG and REG remains relatively constant across treatments.

On a gross level, this parameter is very similar to REG-FPG. An overlay of Figure 7-130 with Figure 7-115 shows that they are strikingly similar in terms of both absolute time differences and the shape of the curves. This similarity, however, disappears within test conditions. Following the auditory probe stimulus, HPG occurs relatively faster after the ECG than does REG for RT conditions than for non-RT conditions.

## FPG-HPG Time Interval

This parameter is the difference in the periods between the T-wave of the ECG and the pulse arrival at the FPG and the HPG sensors (see Figures 7-145 through 7-159). Figure 7-145 represents the averaged time differences on a pulse-by-pulse basis. Zero time indicates simultaneous FPG and HPG arrival times. Positive values indicate that the HPG pulse signal occurs before the FPG pulse signal.

Normally, the HPG pulse occurs prior to the FPG pulse; however, under demanding test conditions, the HPG pulse follows the FPG. Following reaction time responses, FPG tends to lead HPG (see FPG-HPG, Figures 7-148 and 7-149 and Figures 7-152 and 7-154), while for non-RT conditions, HPG leads FPG. This observation is magnified following the 120-db probe tone.

When 120 sec is allowed for task performance, HPG occurs before FPG. When this time is decreased to 80 sec the tendency for FPG to precede HPG increases (see Figures 7-150 and 7-151). This tendency is greatly exacerbated when the contingencies of reaction time and the more difficult game task are included. (Compare Figures 7-152 and 7-153, and Figures 7-156 and 7-157).

The greatest variability in this parameter occurs under the most difficult task condition (Figure 7-156); the least variability occurs under the easiest task conditions (Figures 7-155 and 7-159).
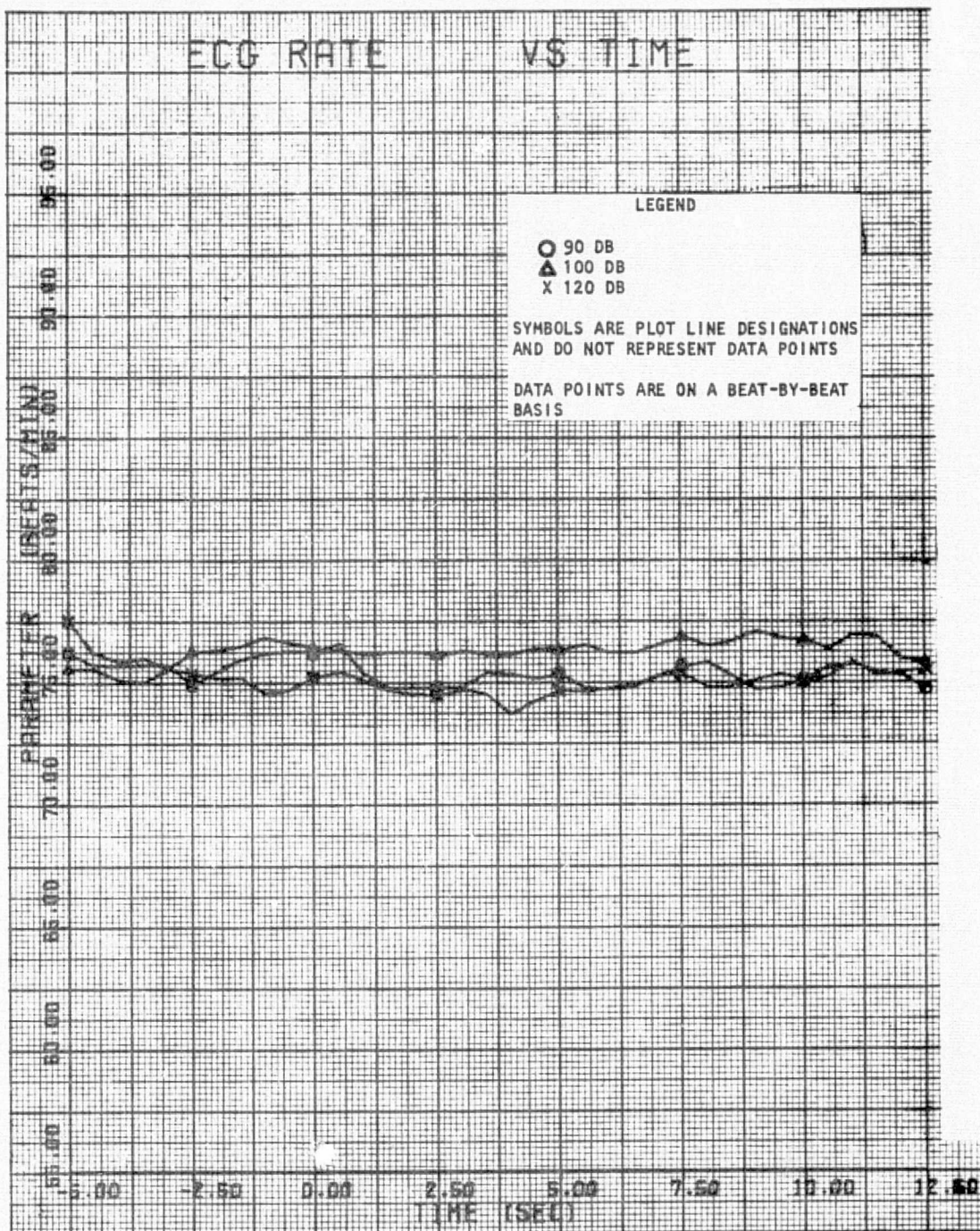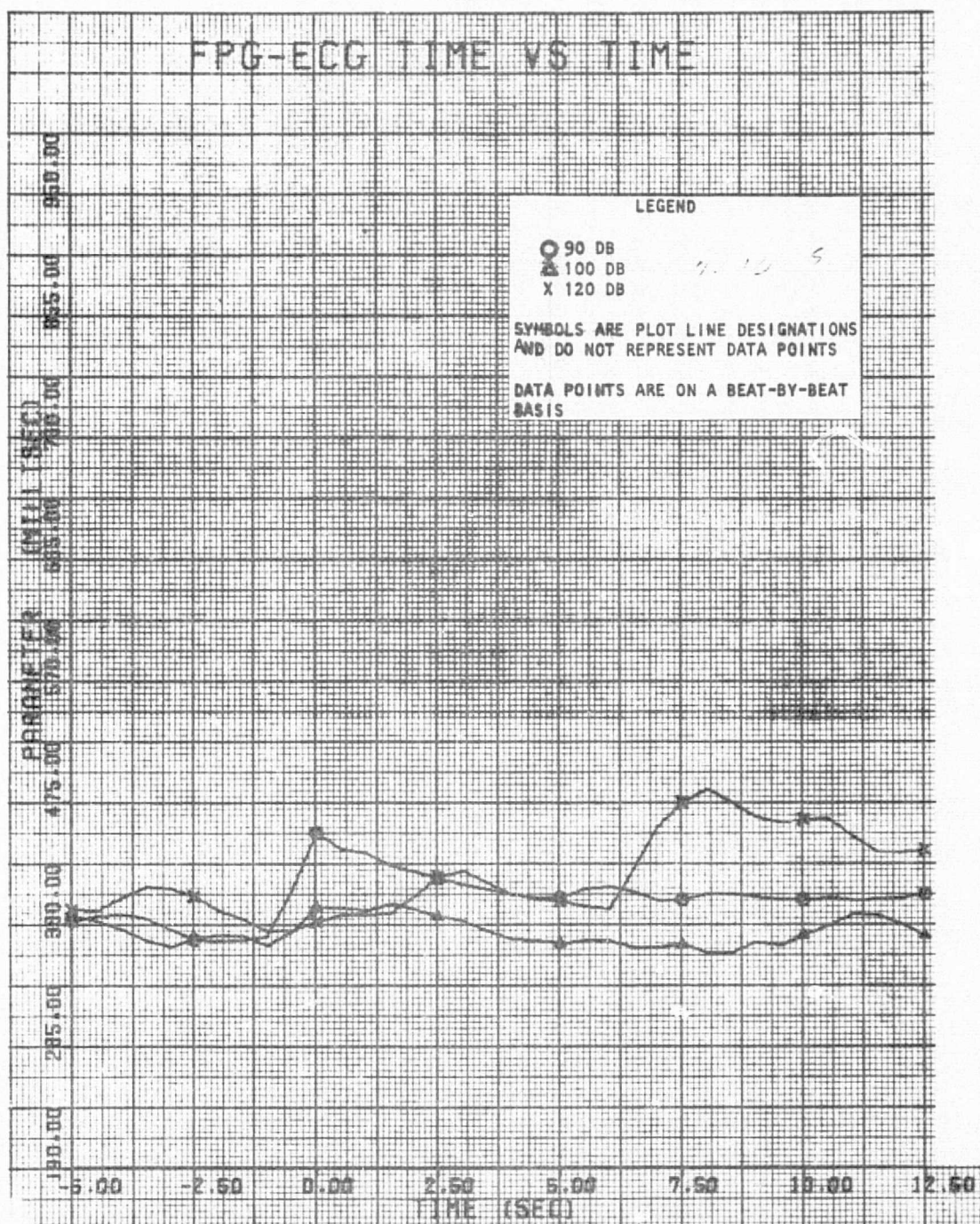
Figure 7-10. Heart Rate for Test Day 3,
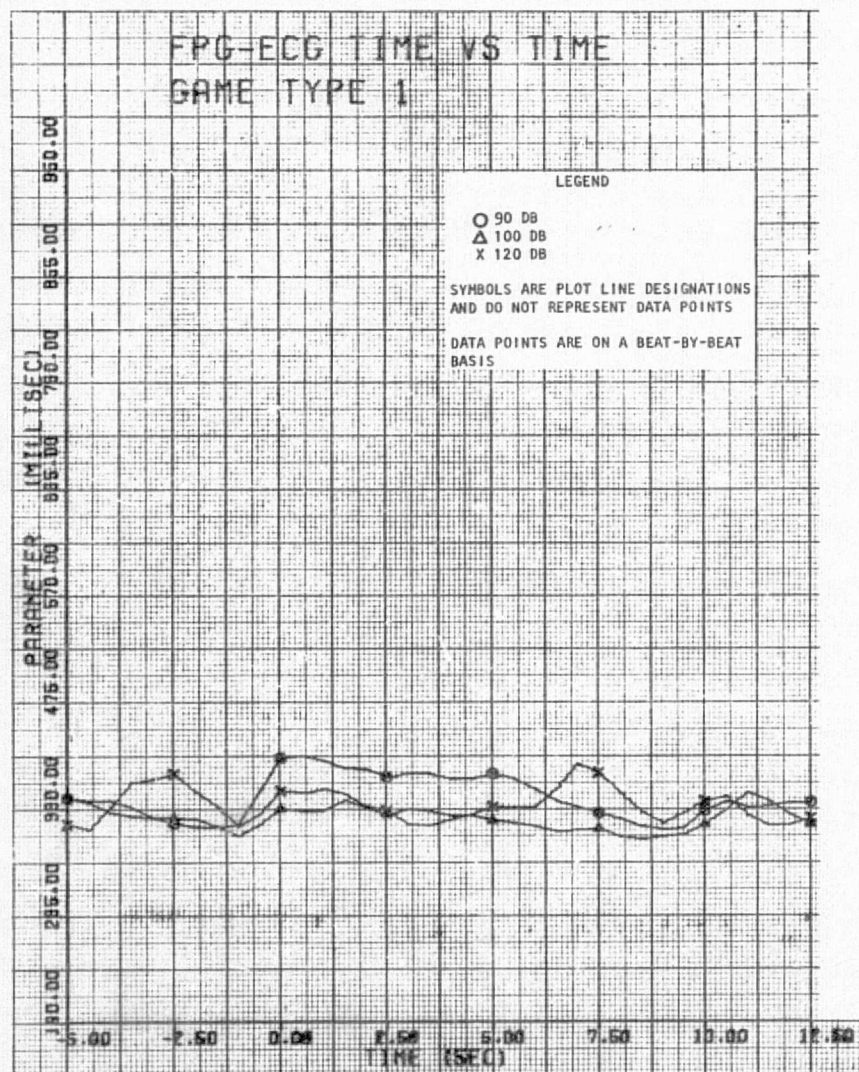Conditions 5 and 6 (Less
110 db, 100-Sec Task
Duration, VM Task 3)
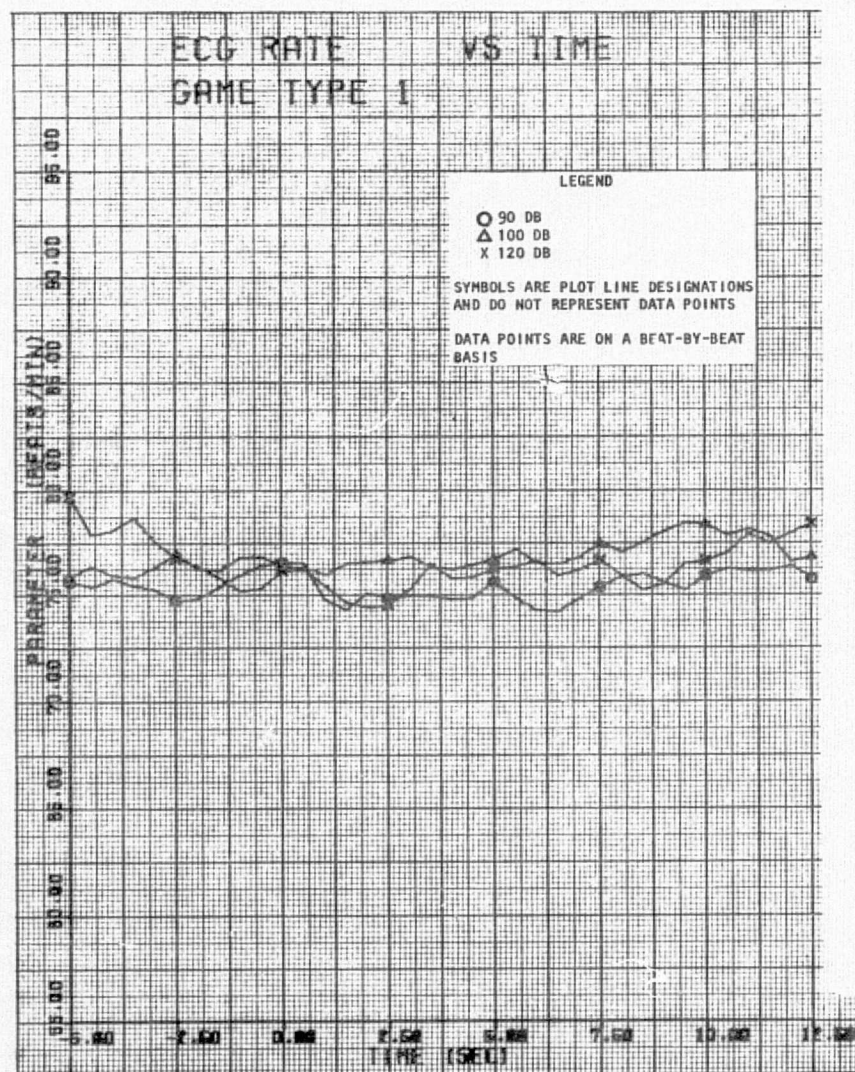
Figure 7-11. Heart Rate for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1
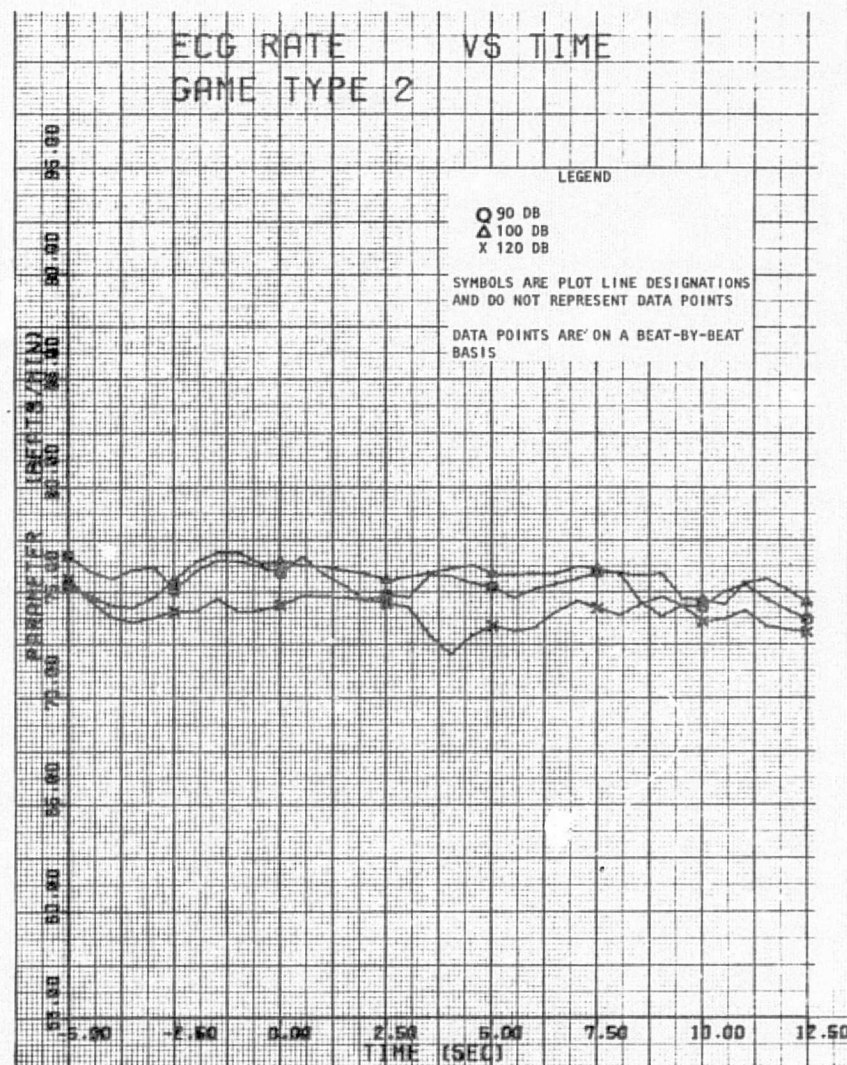
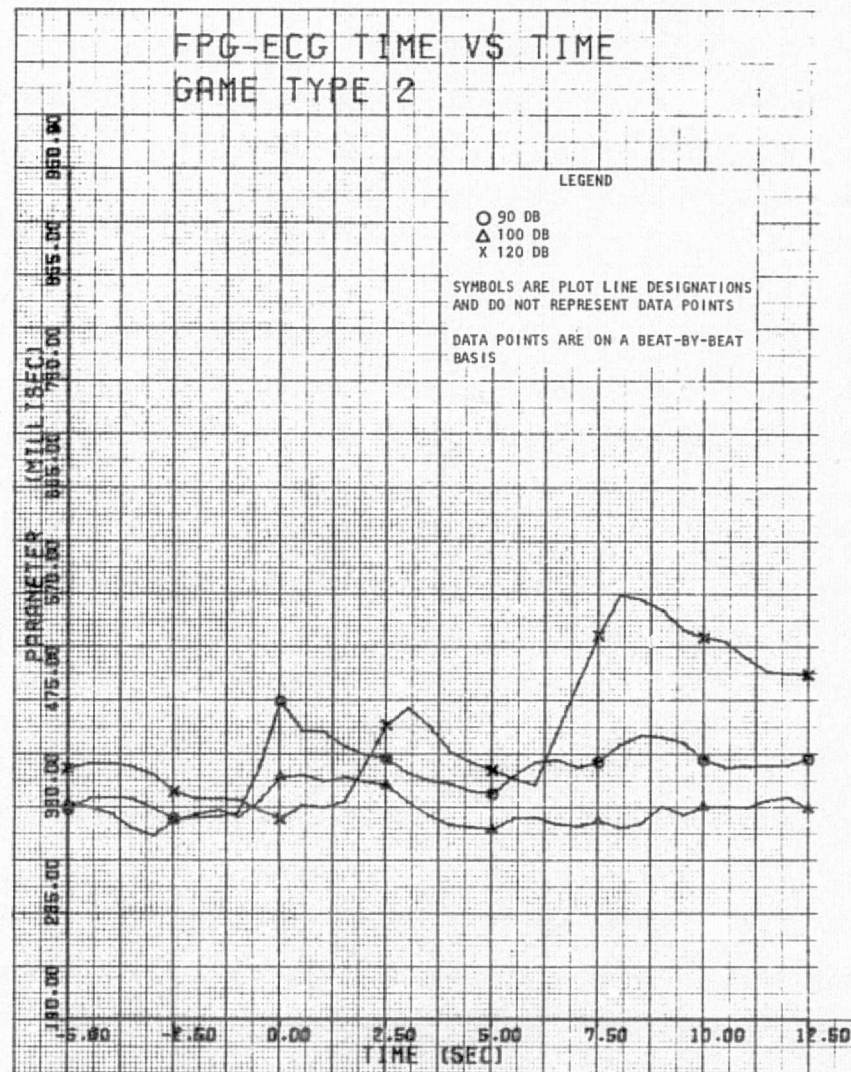Figure 7-12. Heart Rate for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 2
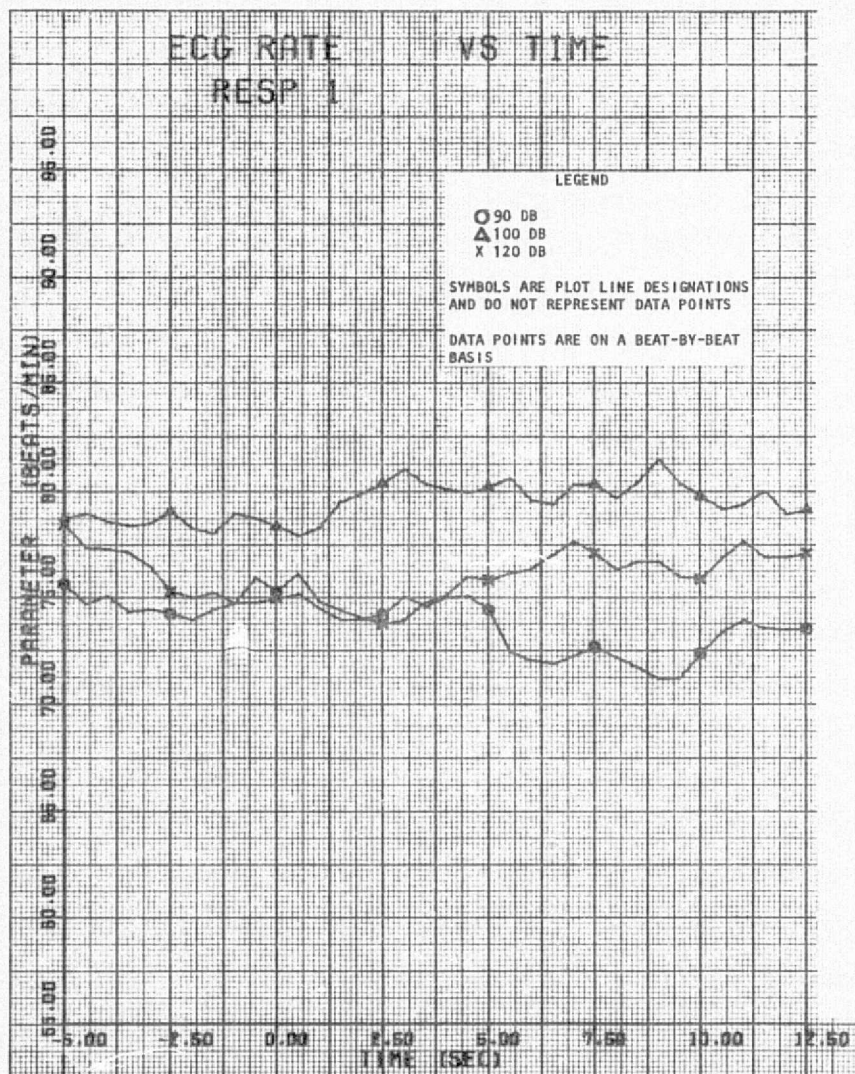
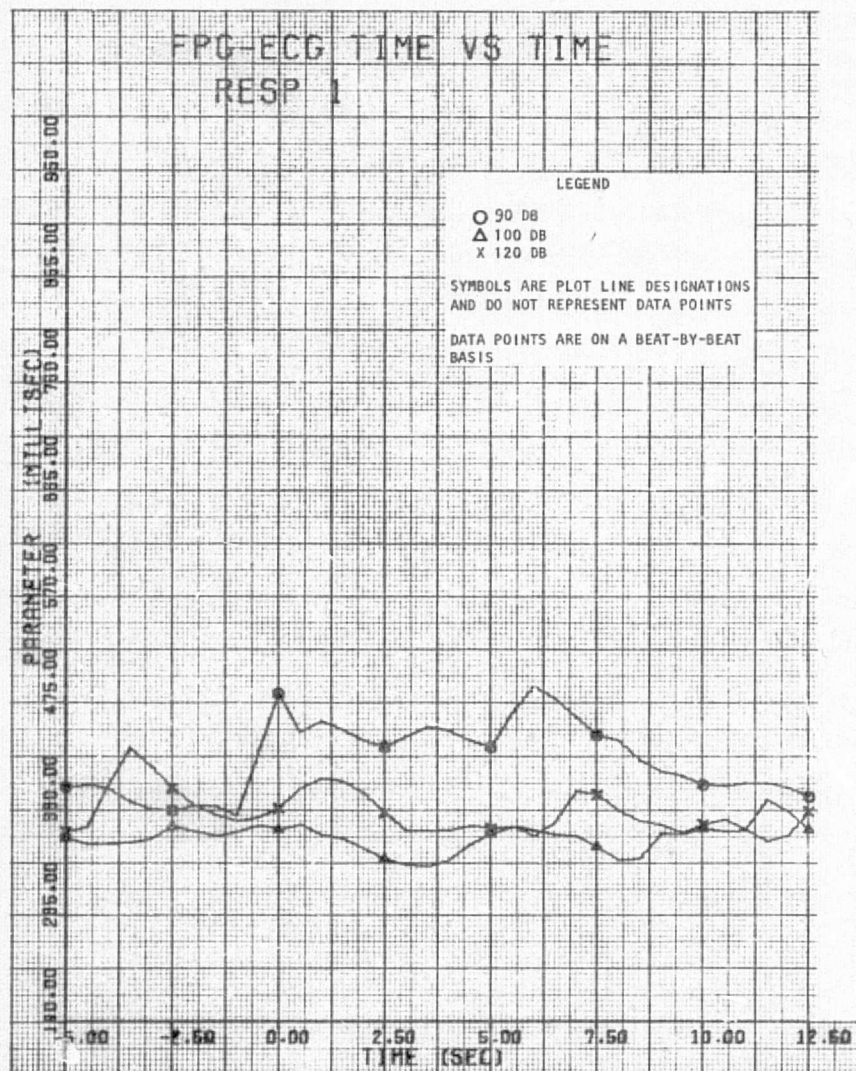Figure 7-13.  Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
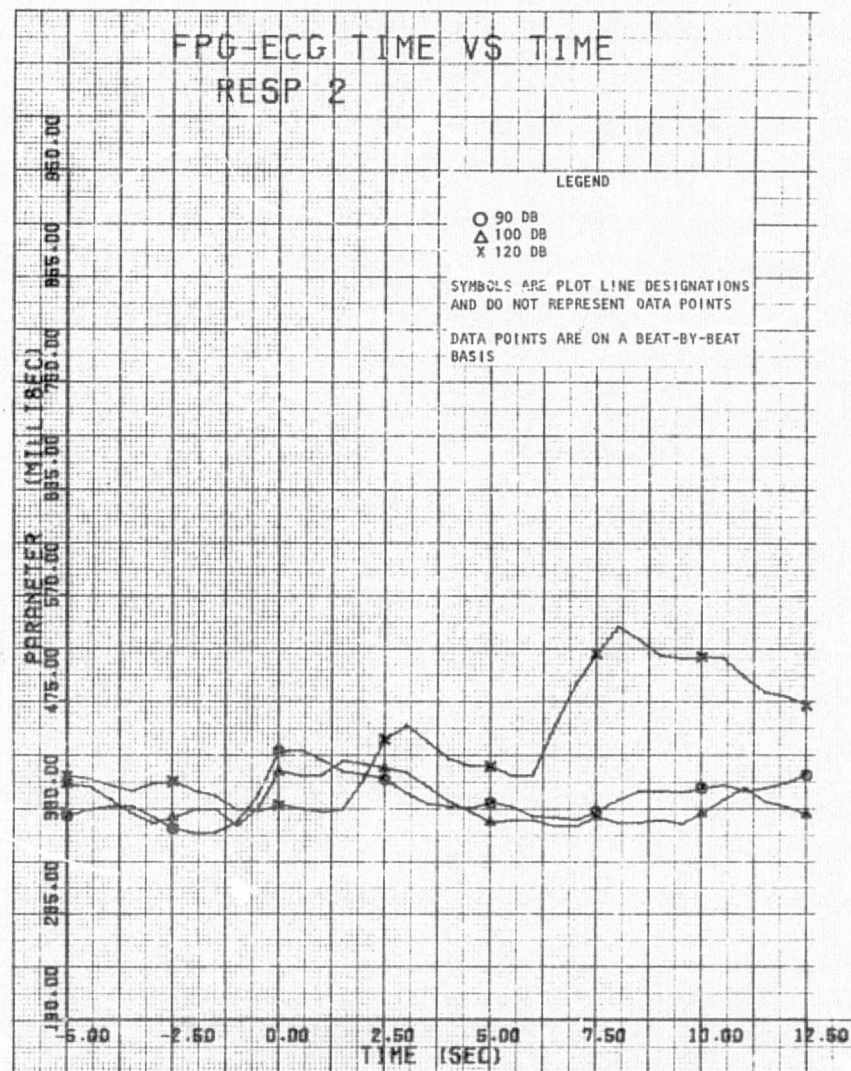100-Sec Task Duration, VM Task 3)
--Response 1
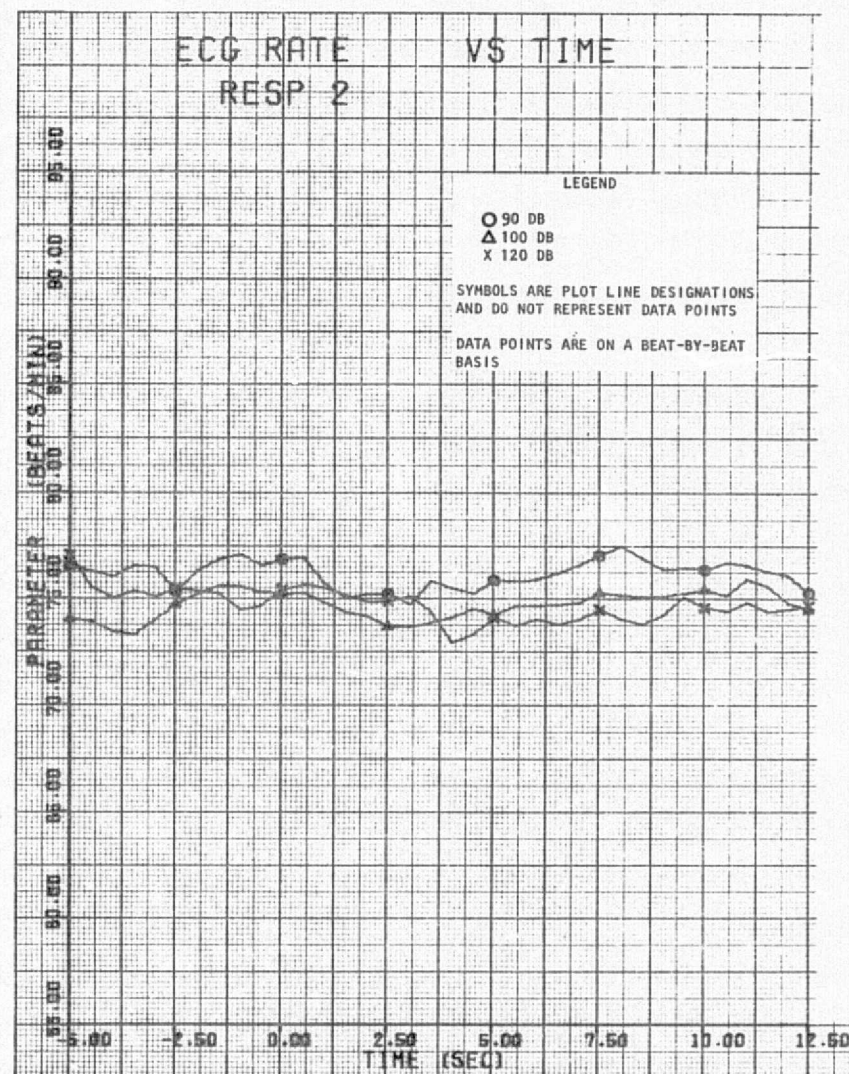


Figure 7-14.  Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
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--Response 2
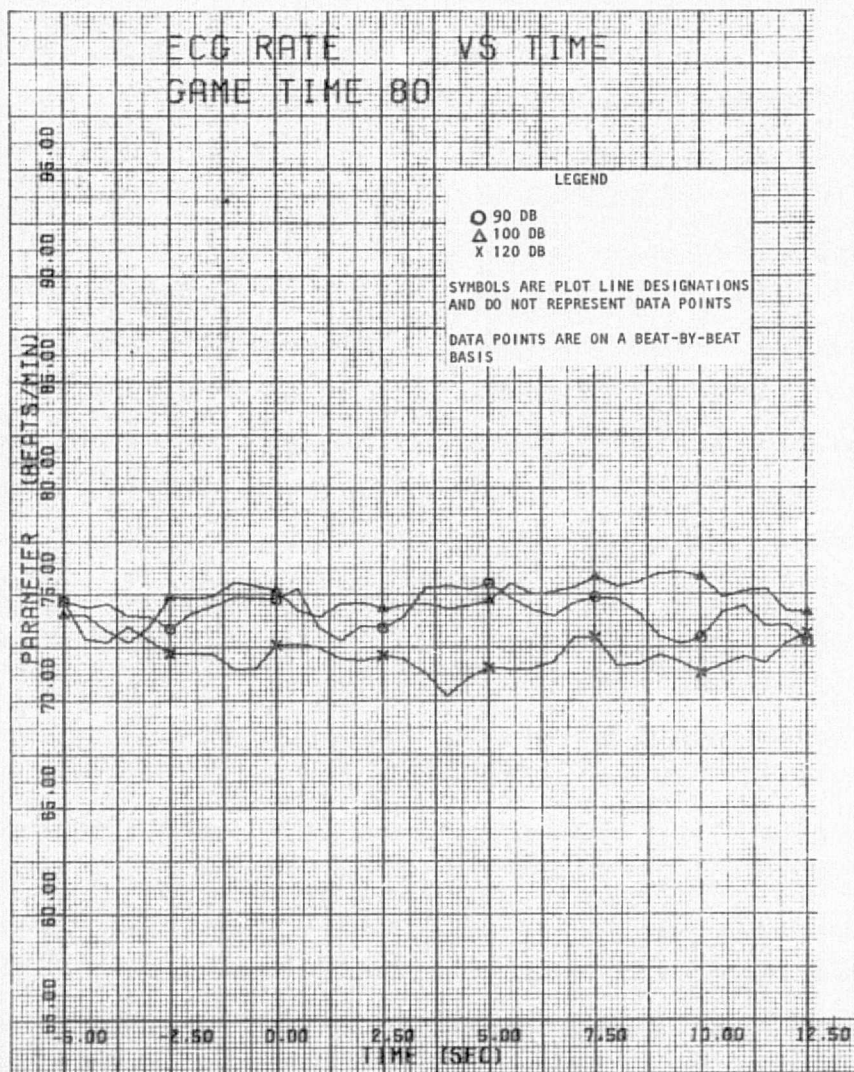
Figure 7-15. Heart Rate for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --80-Sec Game Time
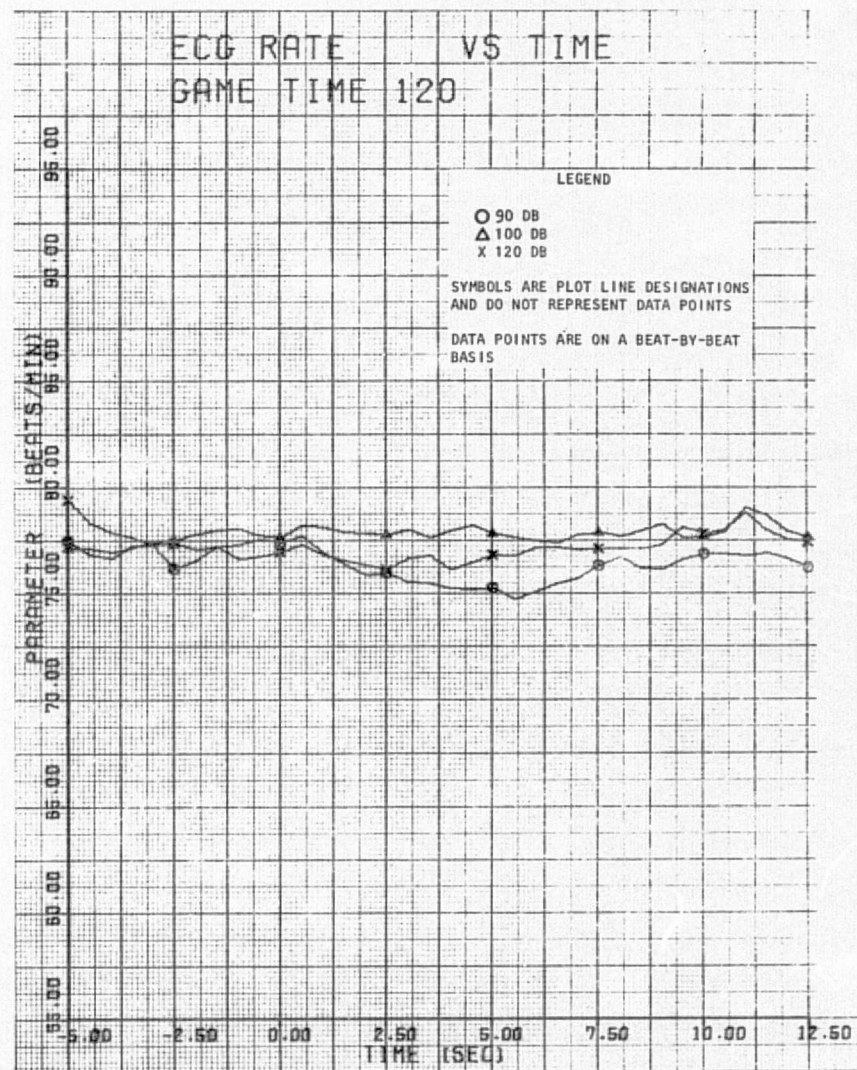
Figure 7-16. Heart Rate for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --120-Sec Game Time
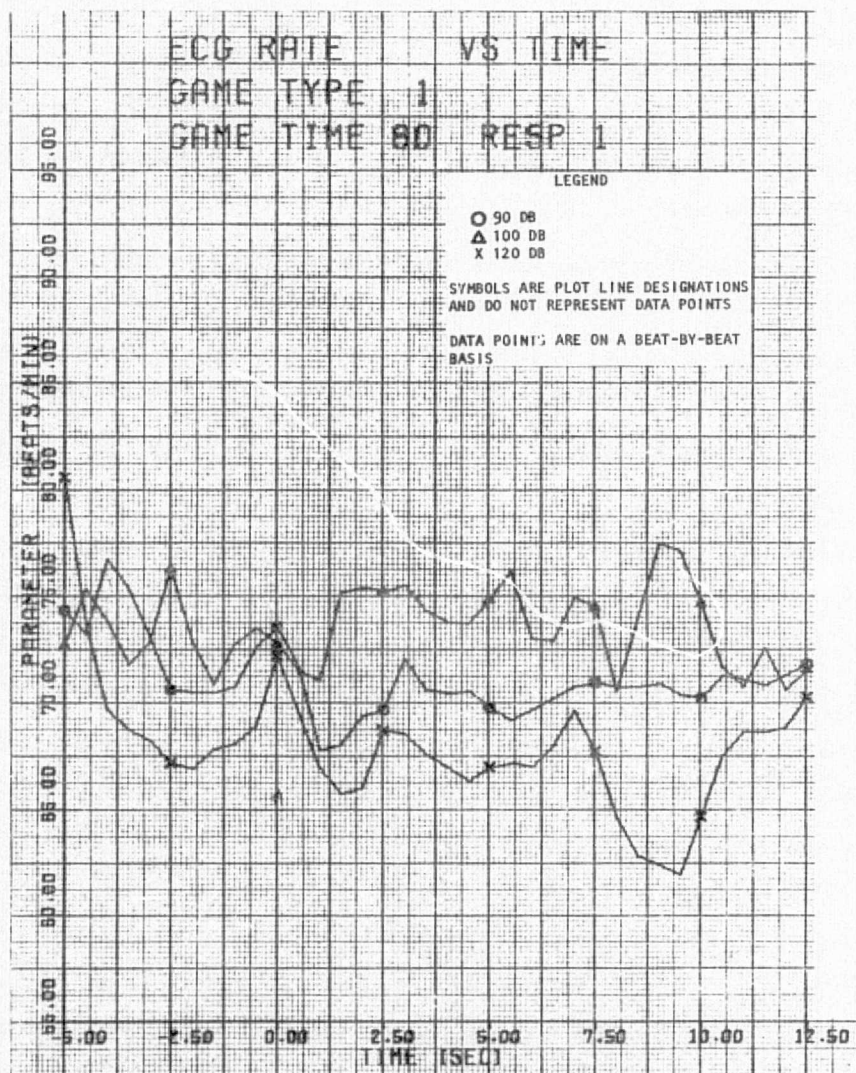
Figure 7-17. Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
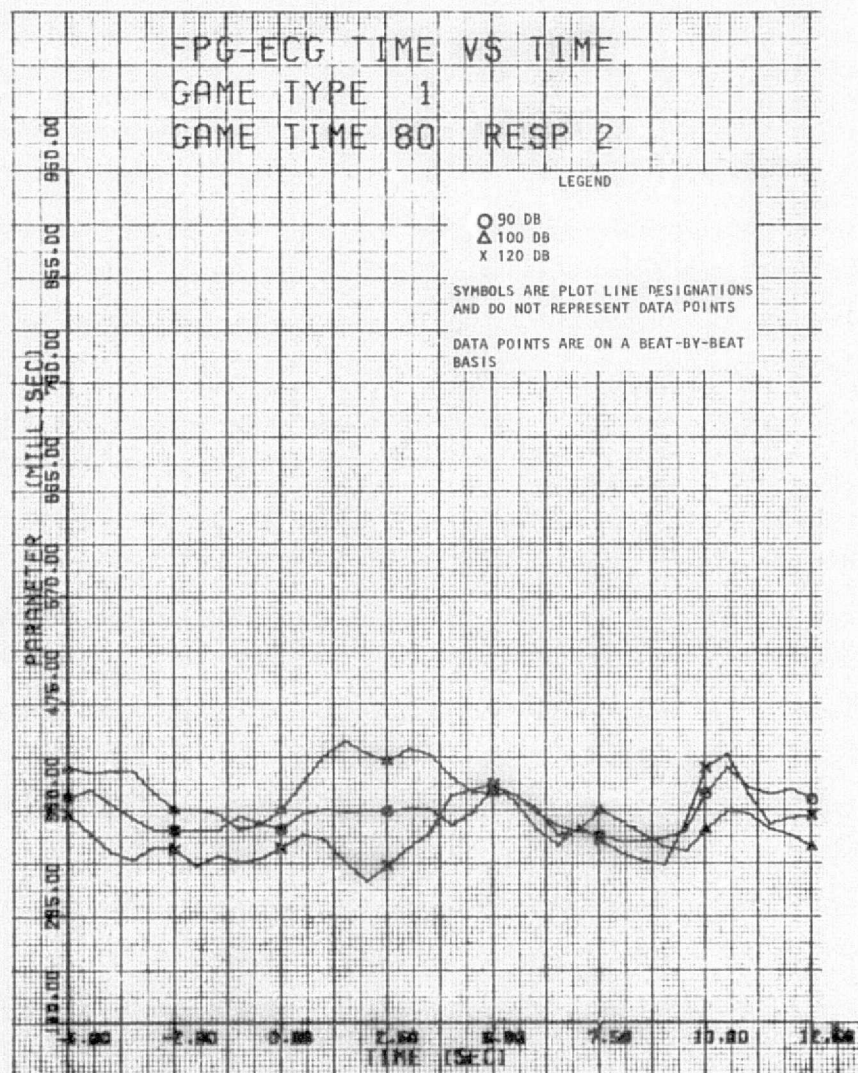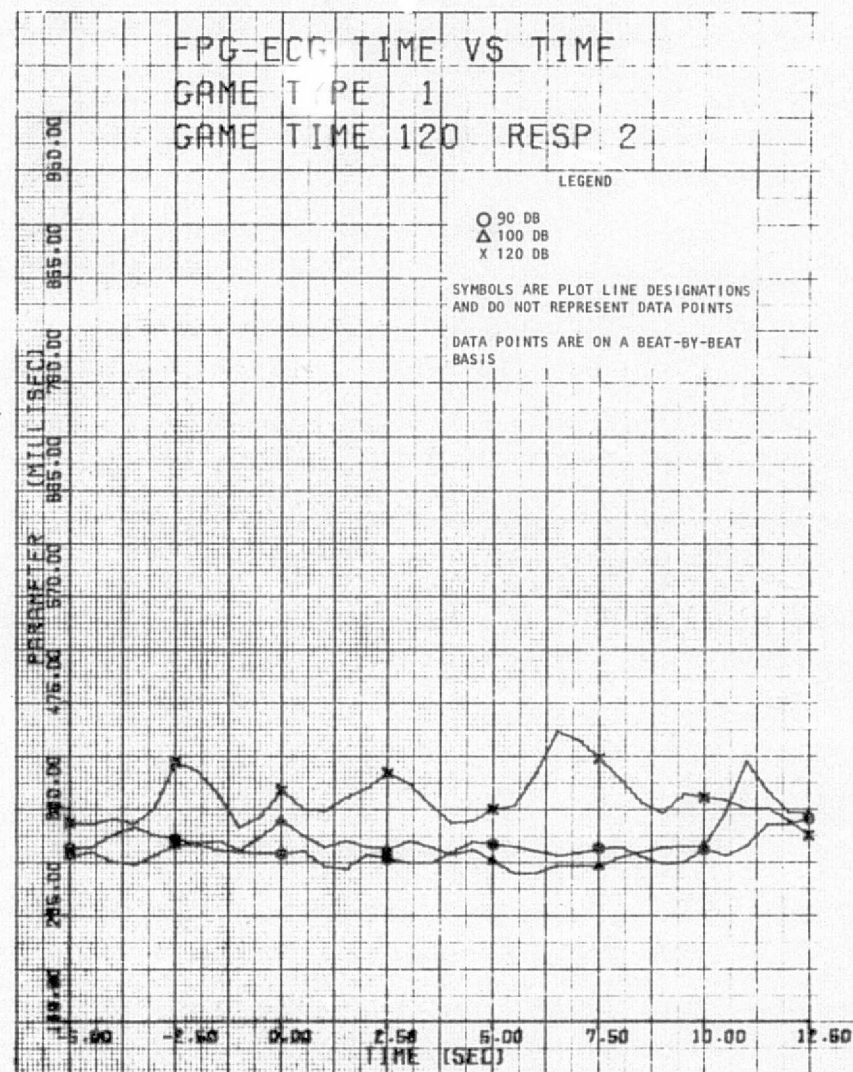--Game Type 1, 80-Sec Game Time,
Response 1
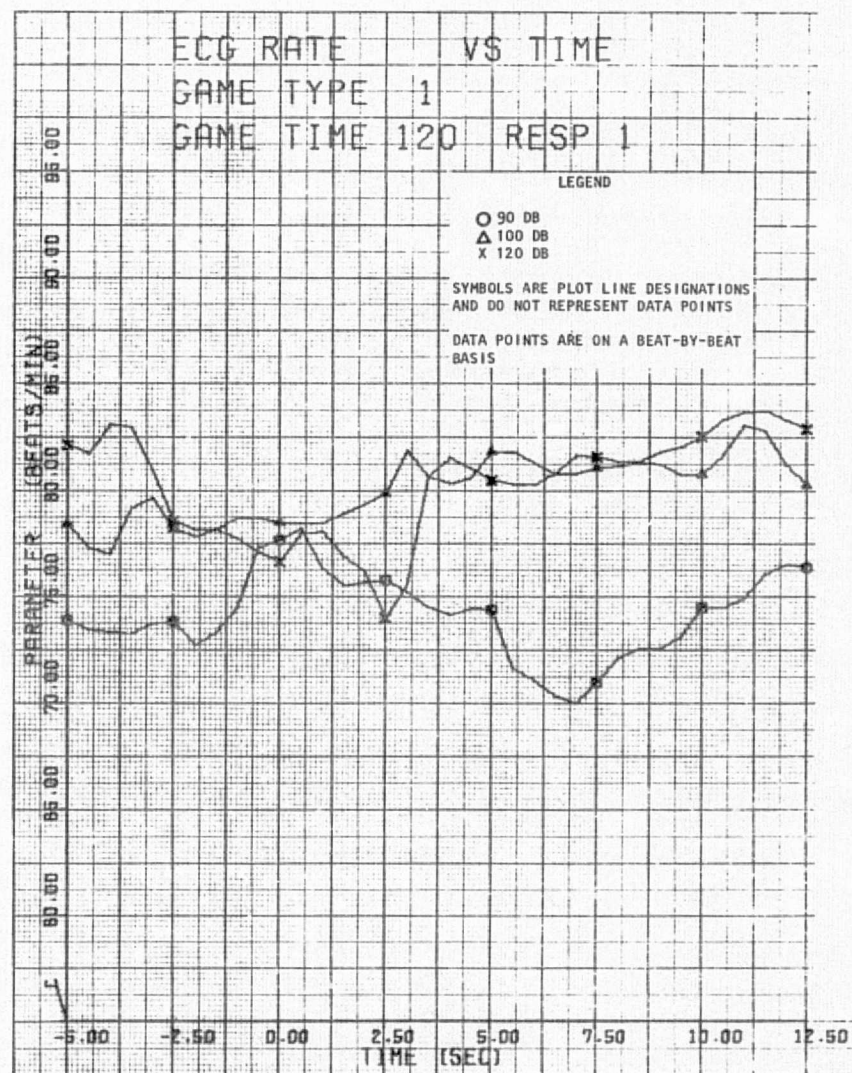


Figure 7-18. Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 1, 120-Sec Game Time,
Response 1
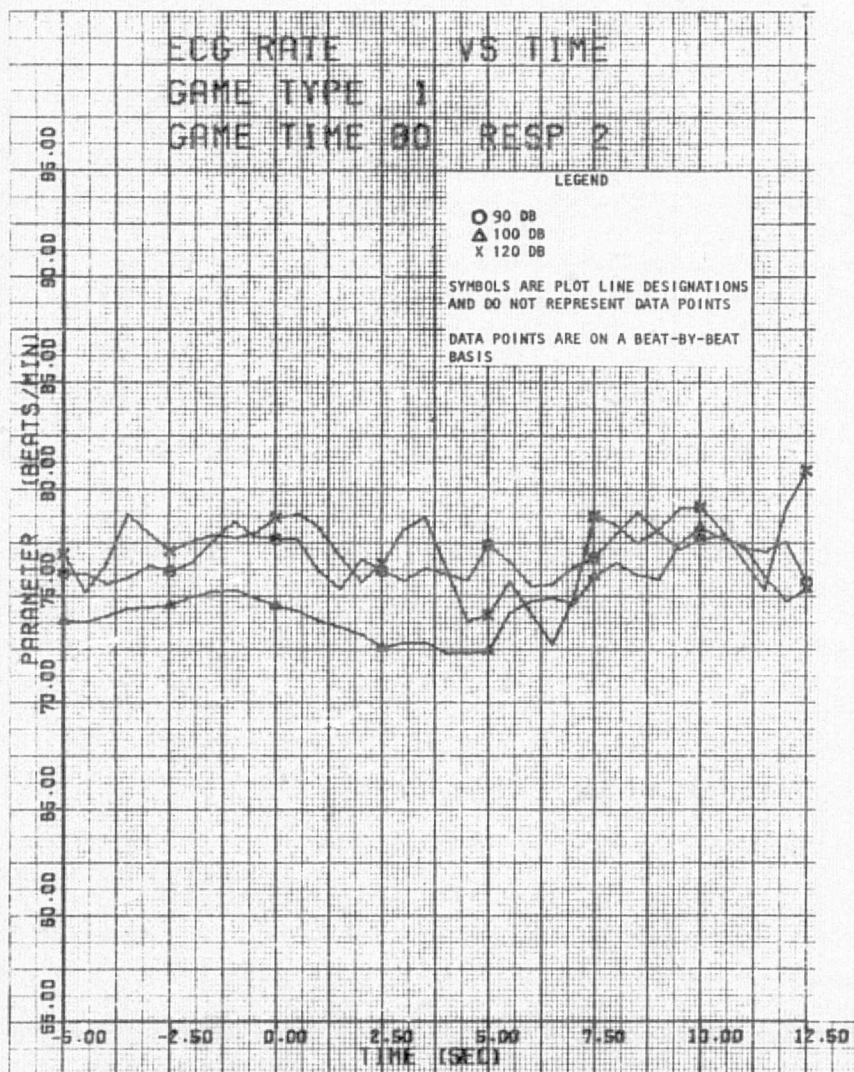
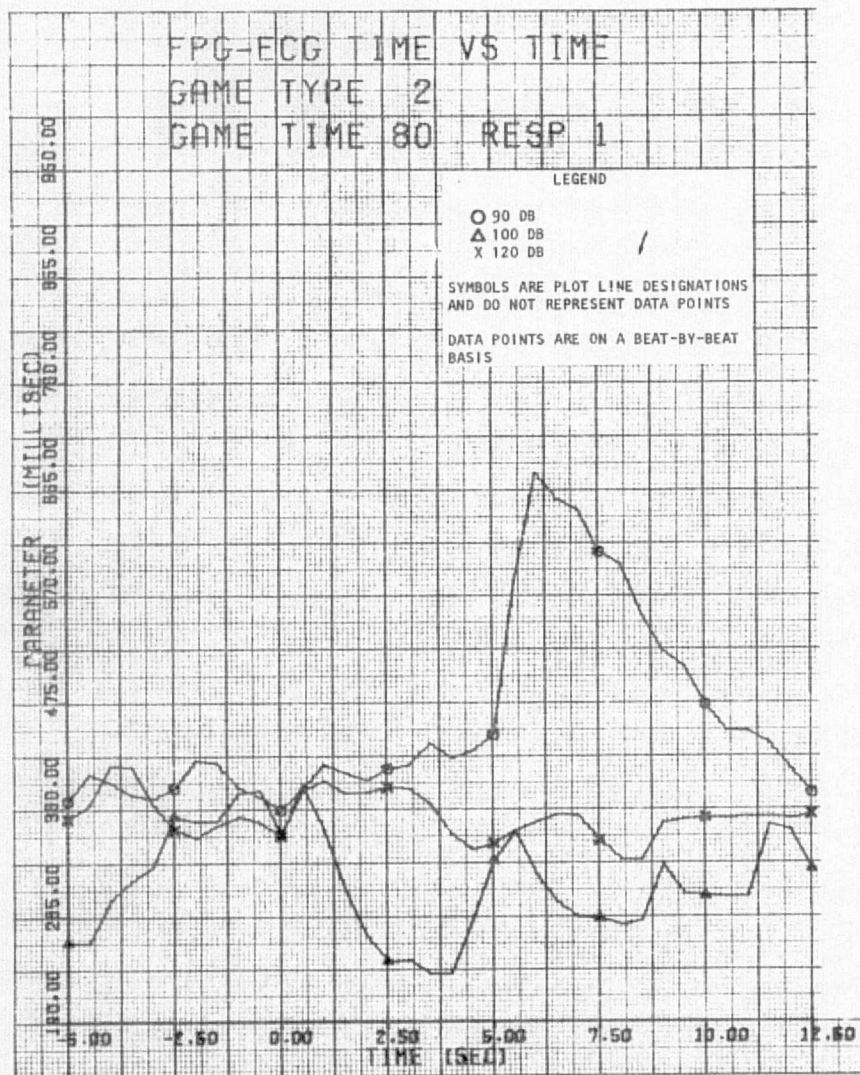Figure 7-19. Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
110 db, 100-Sec Task Duration,
VM Task 3)--Game Type 1,
80-Sec Game Time, Response 2
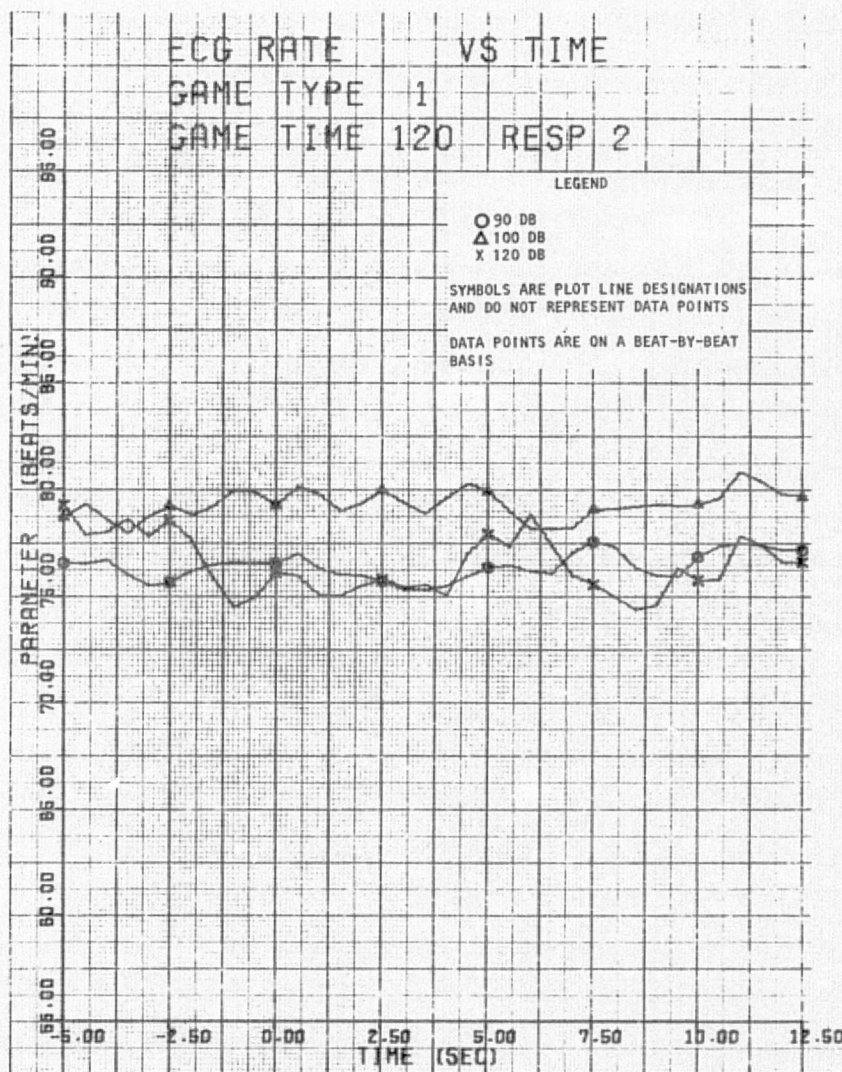


Figure 7-20. Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 1, 120-Sec Game Time,
Response 2
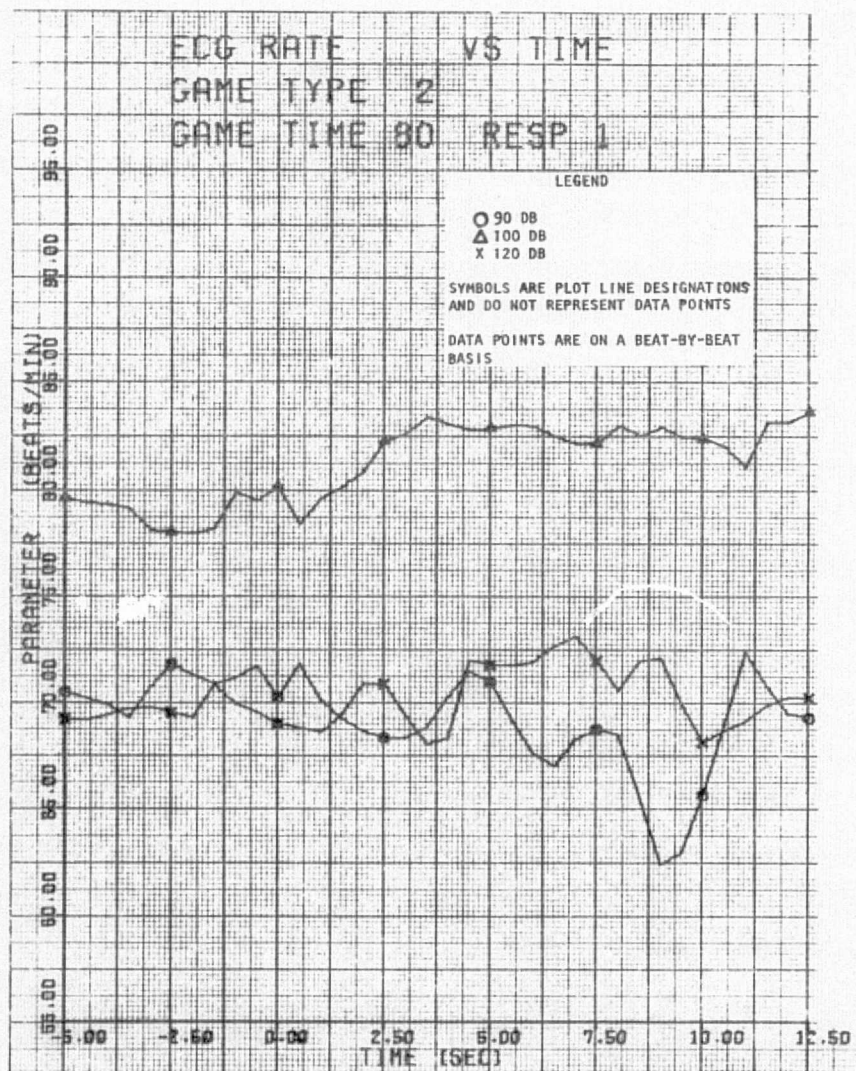
Figure 7-21.  Heart Rate for Test Day 3,
             Conditions 5 and 6 (Less 110 db,
             100-Sec Task Duration, VM Task 3)
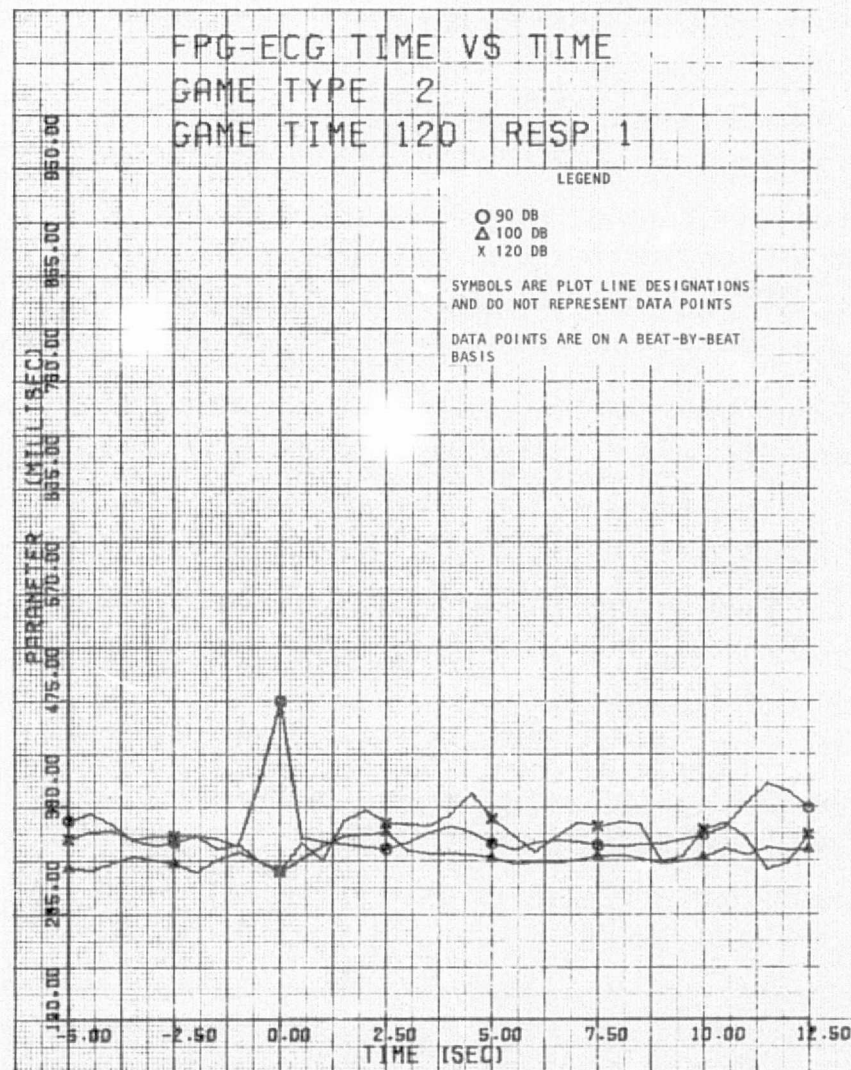             --Game Type 2, 80-Sec Game Time,
             Response 1
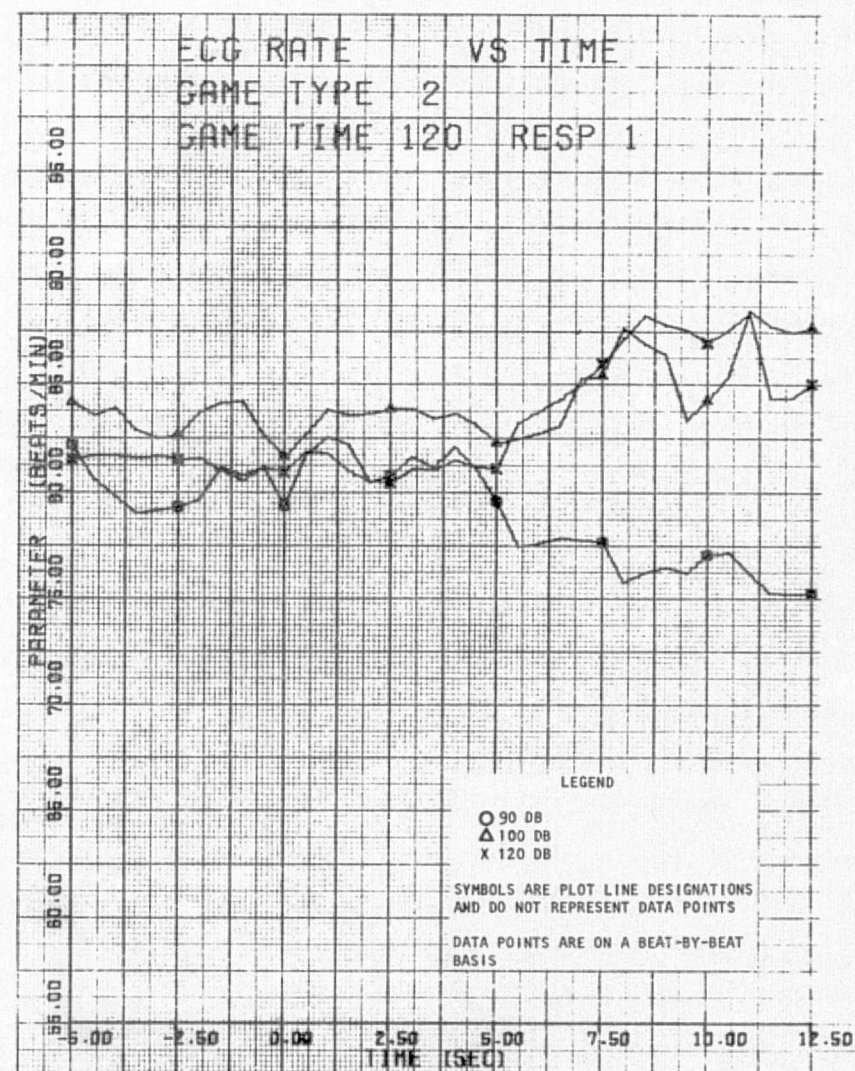
Figure 7-22.  Heart Rate for Test Day 3,
             Conditions 5 and 6 (Less 110 db,
             100-Sec Task Duration, VM Task 3)
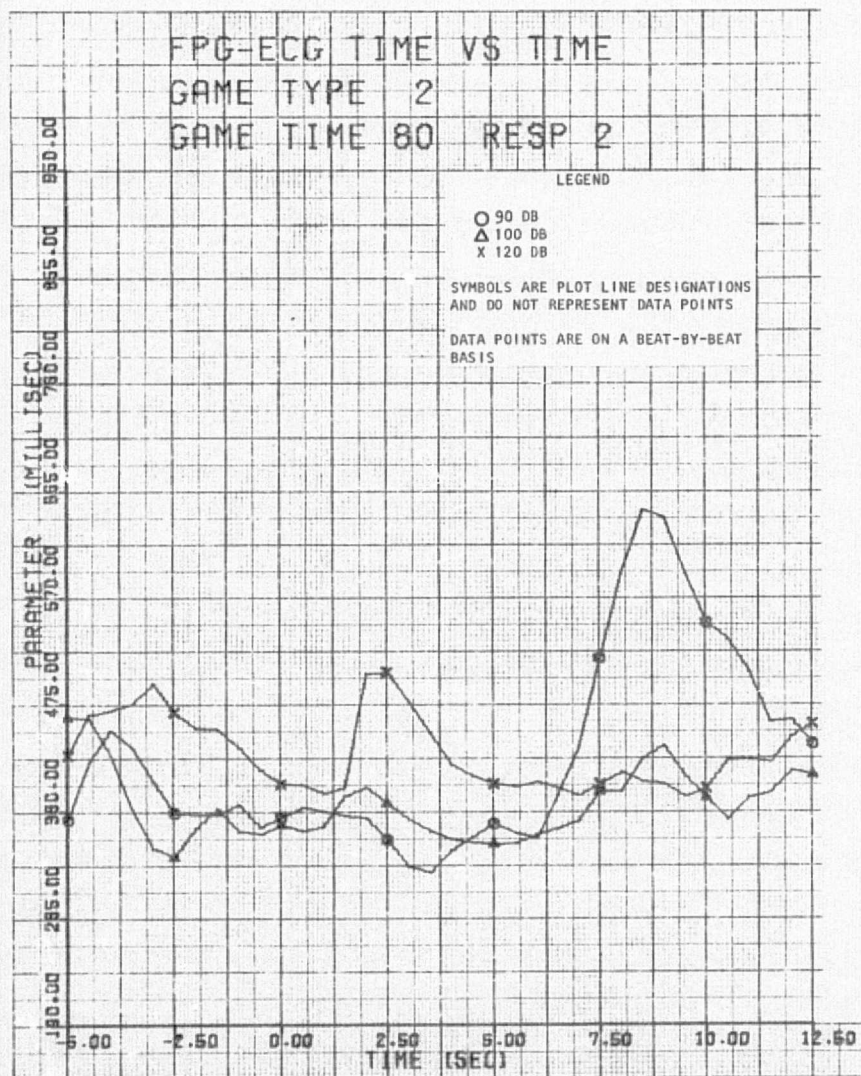             --Game Type 2, 120-Sec Game Time,
             Response 1
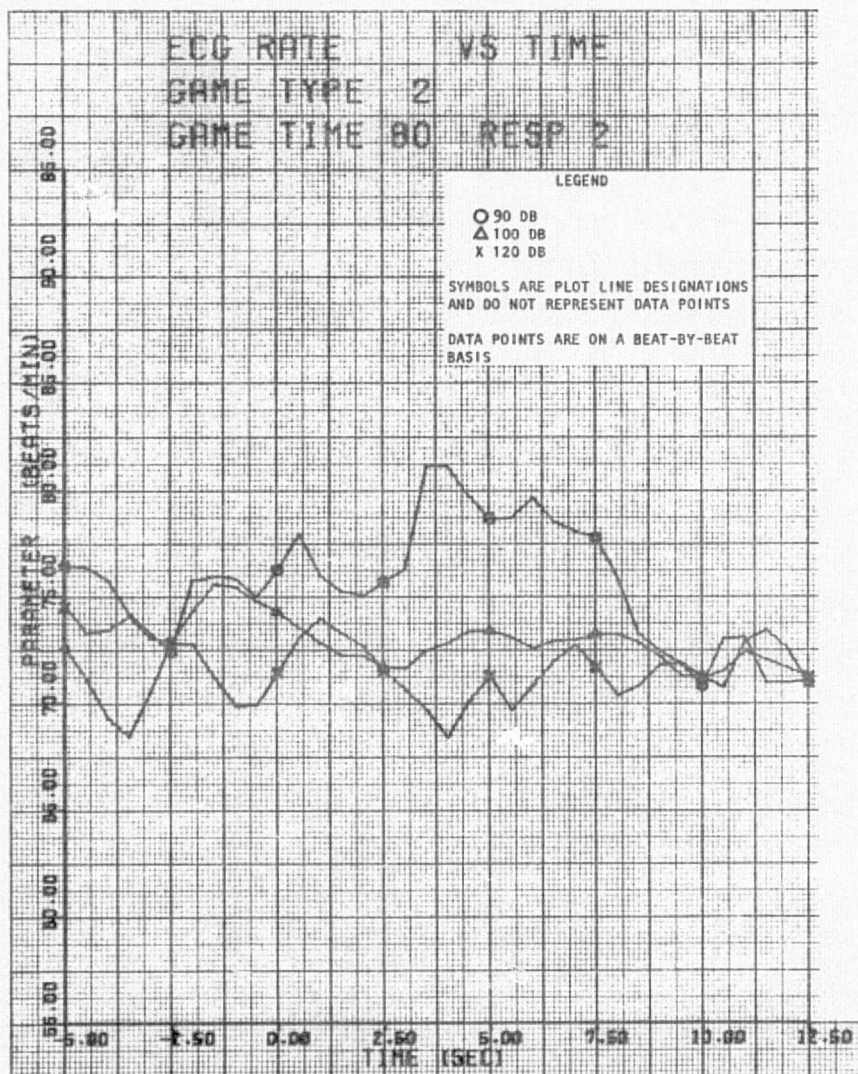
Figure 7-23. Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 2, 80-Sec Game Time,
Response 2
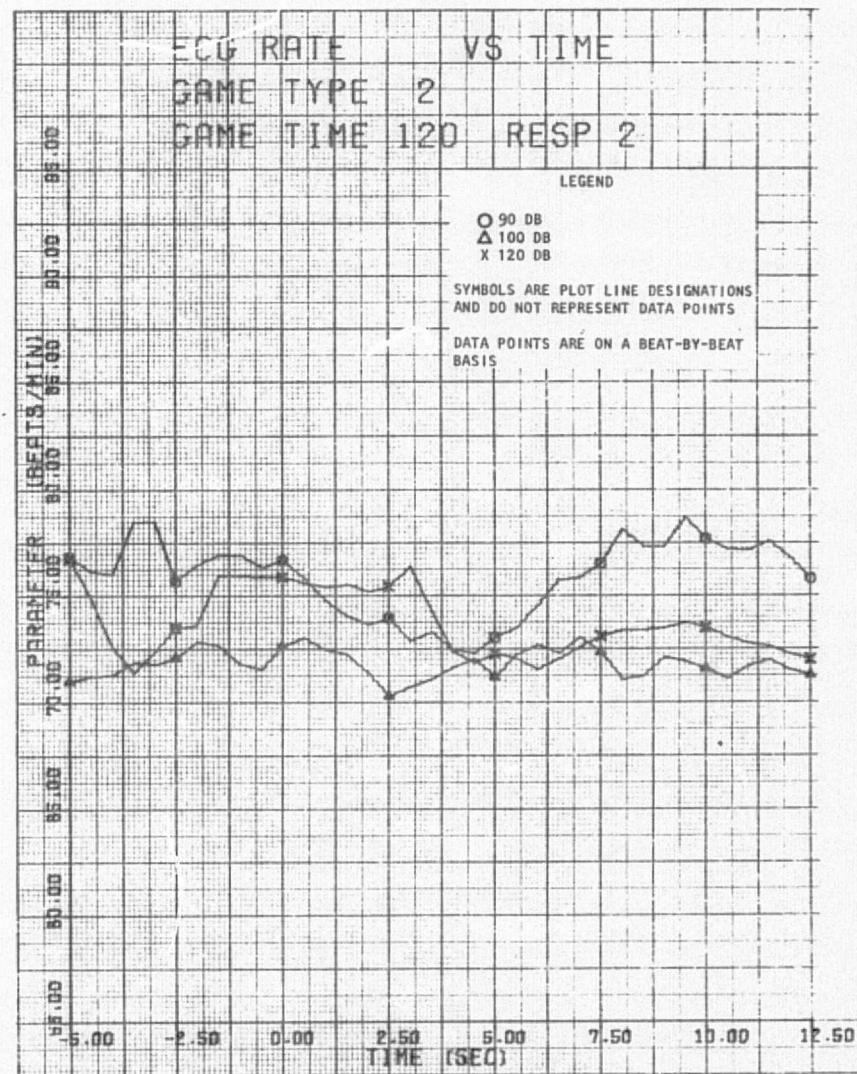
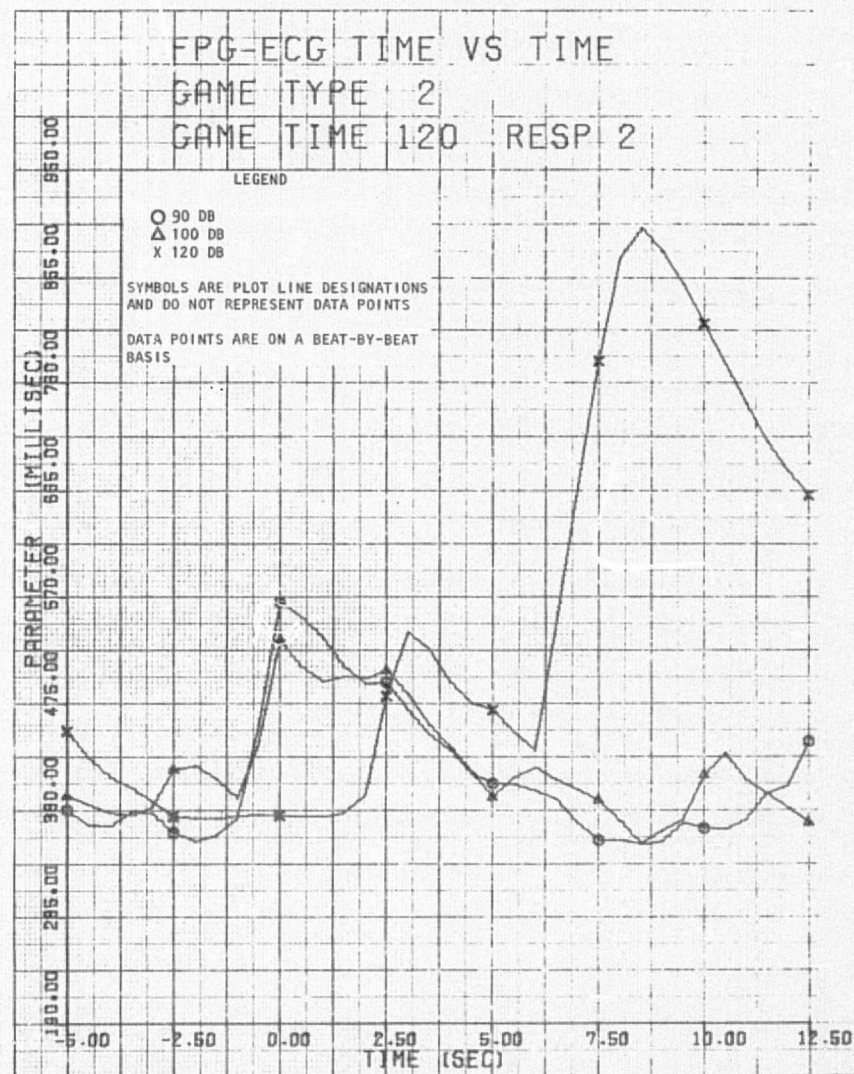Figure 7-24. Heart Rate for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 2, 120-Sec Game Time,
Response 2
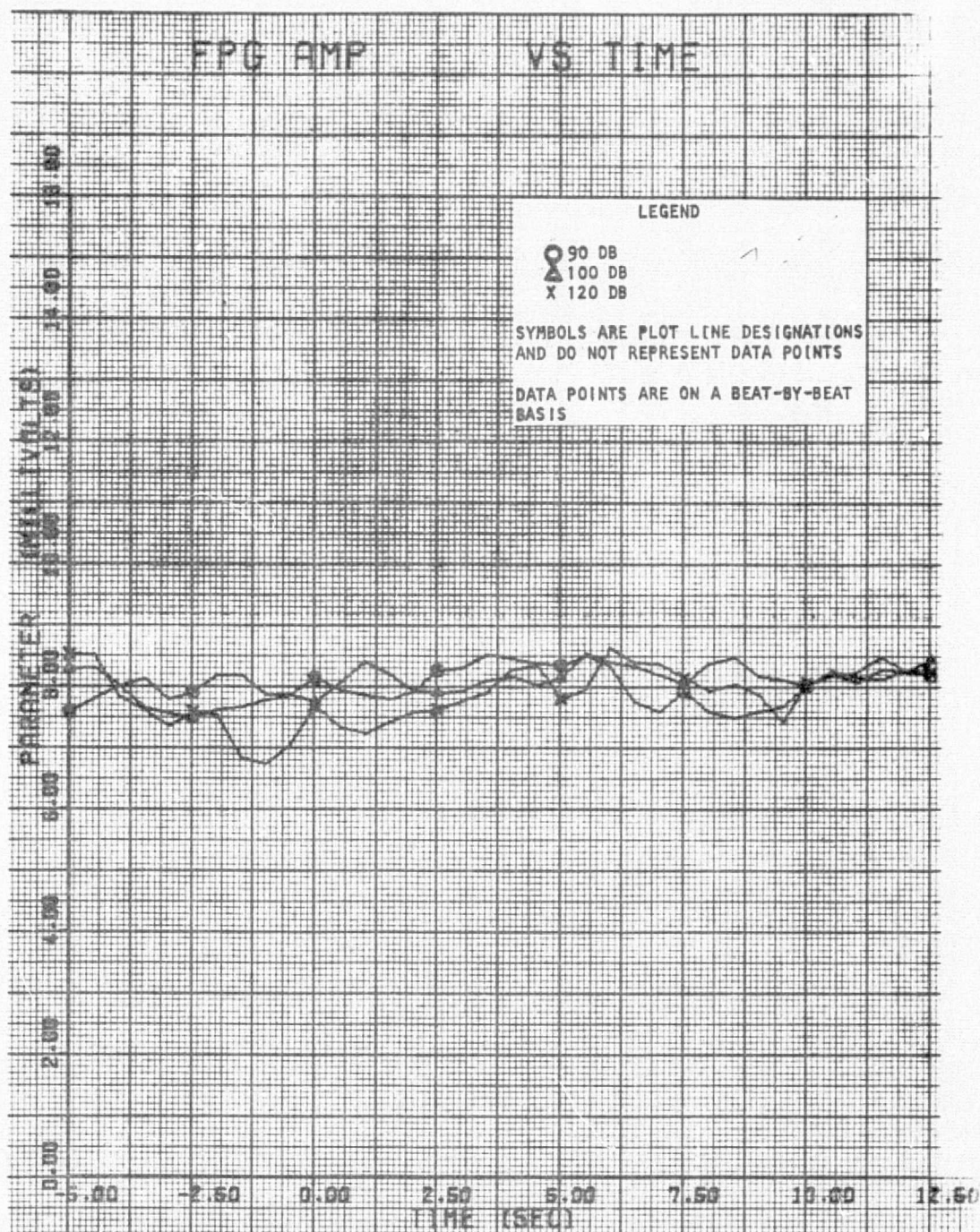
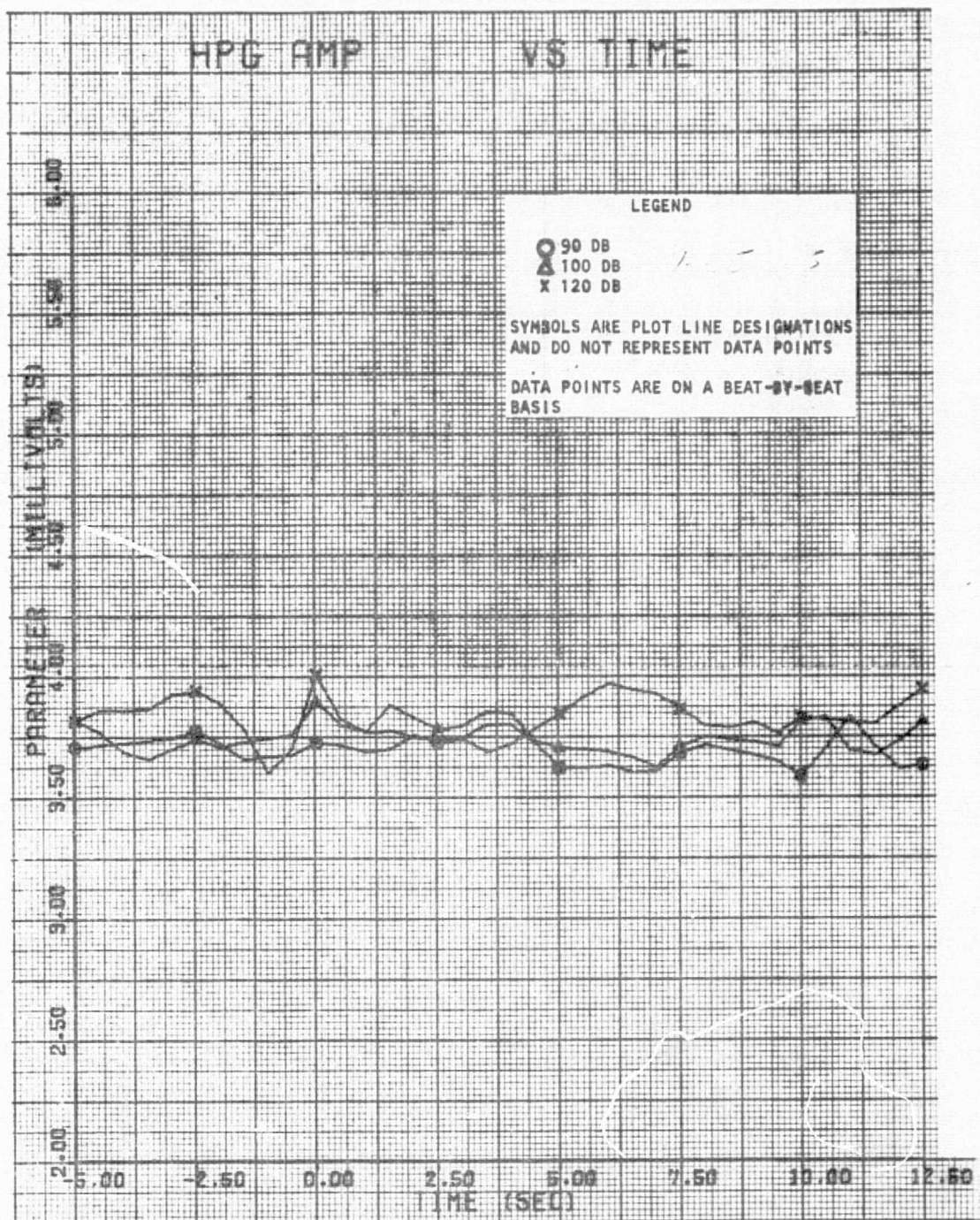Figure 7-25. FPG Pulse Amplitude for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
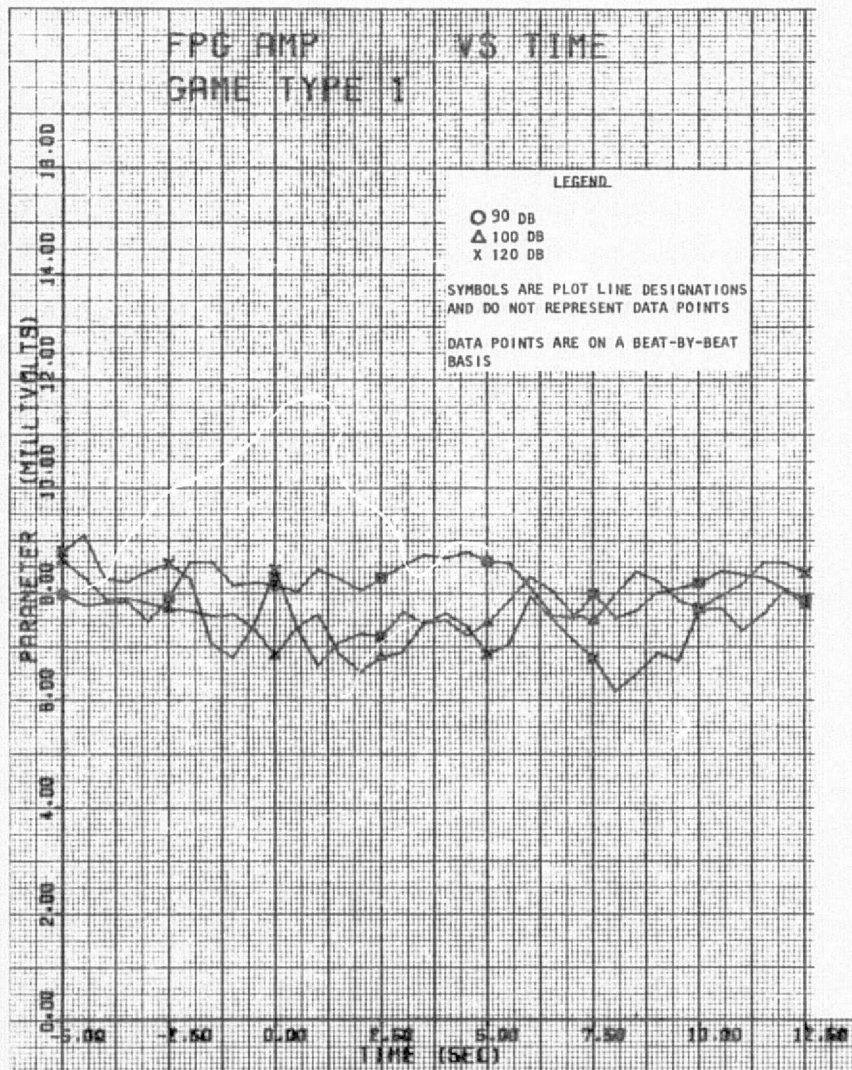
Figure 7-26.  FPG Pulse Amplitude for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 1
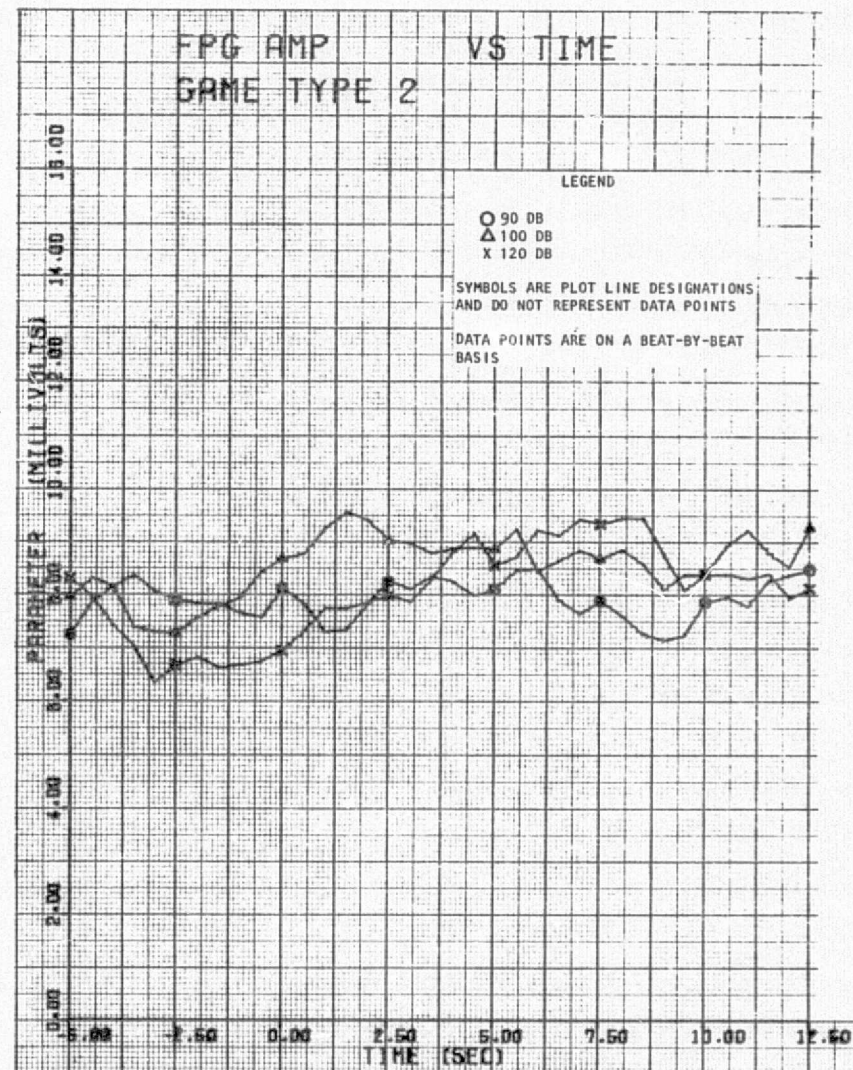
Figure 7-27.  FPG Pulse Amplitude for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 2
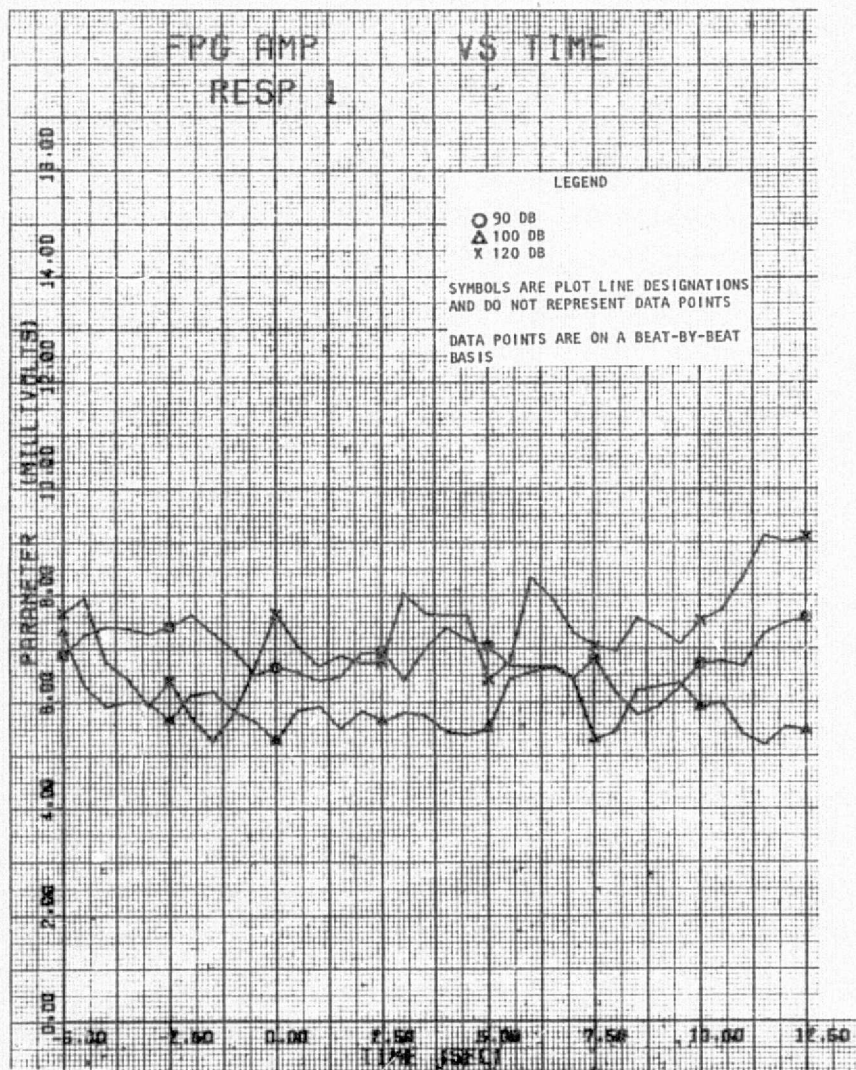
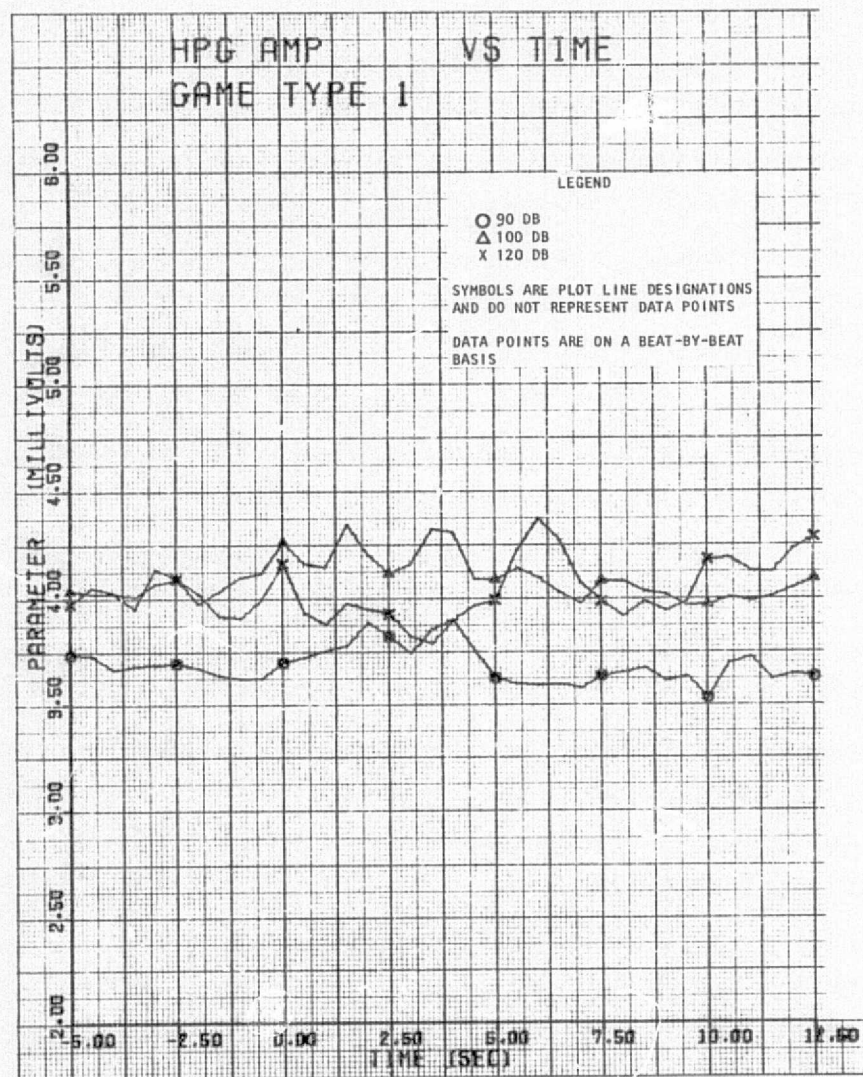Figure 7-28. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Response 1
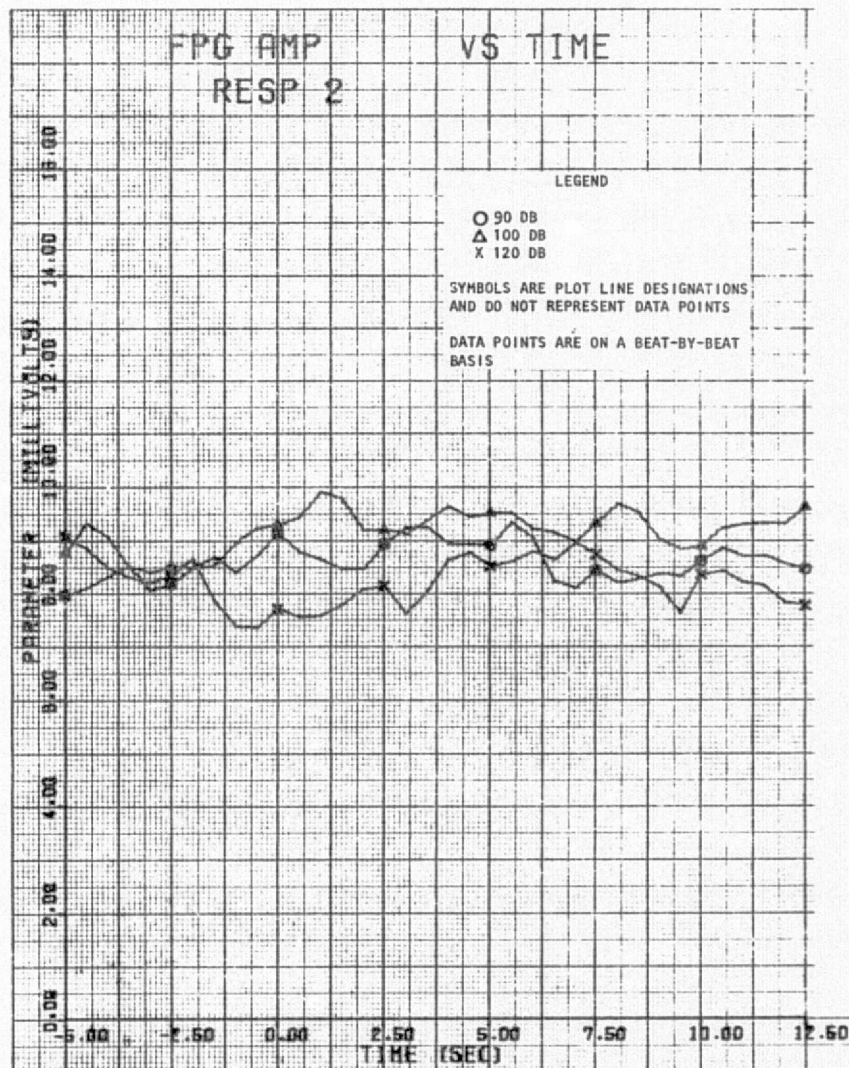
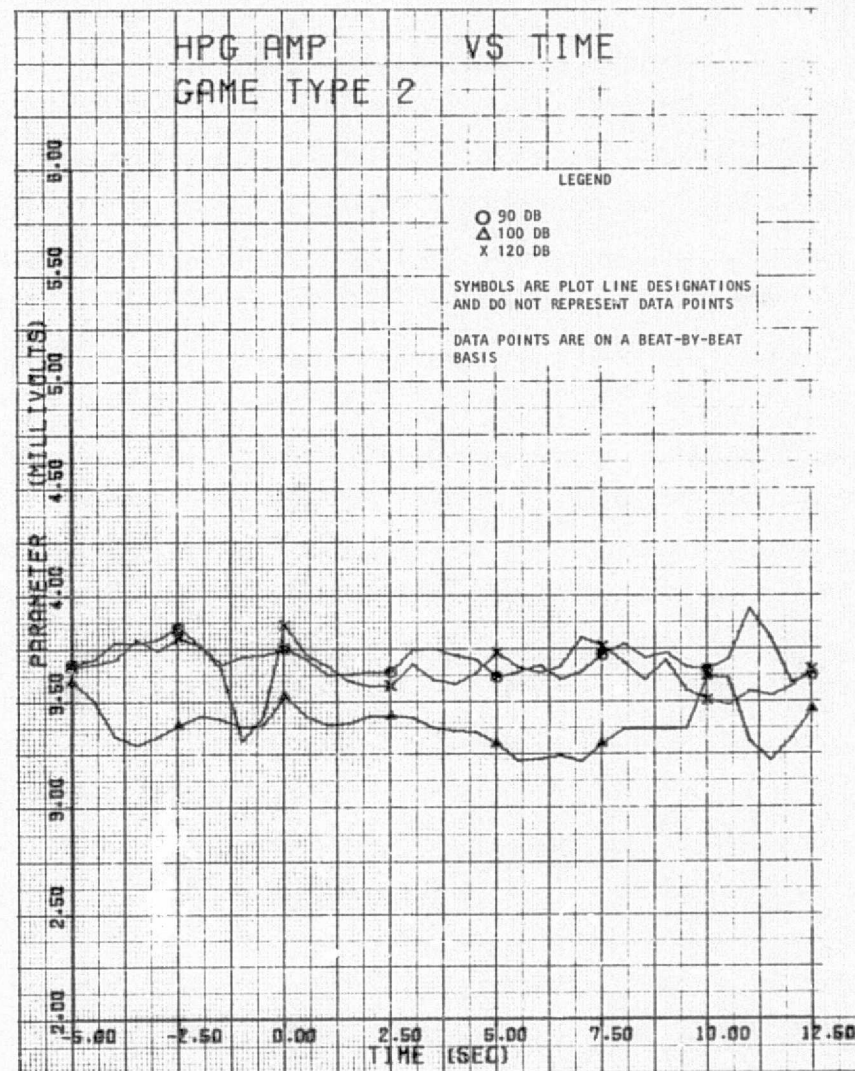Figure 7-29. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Response 2
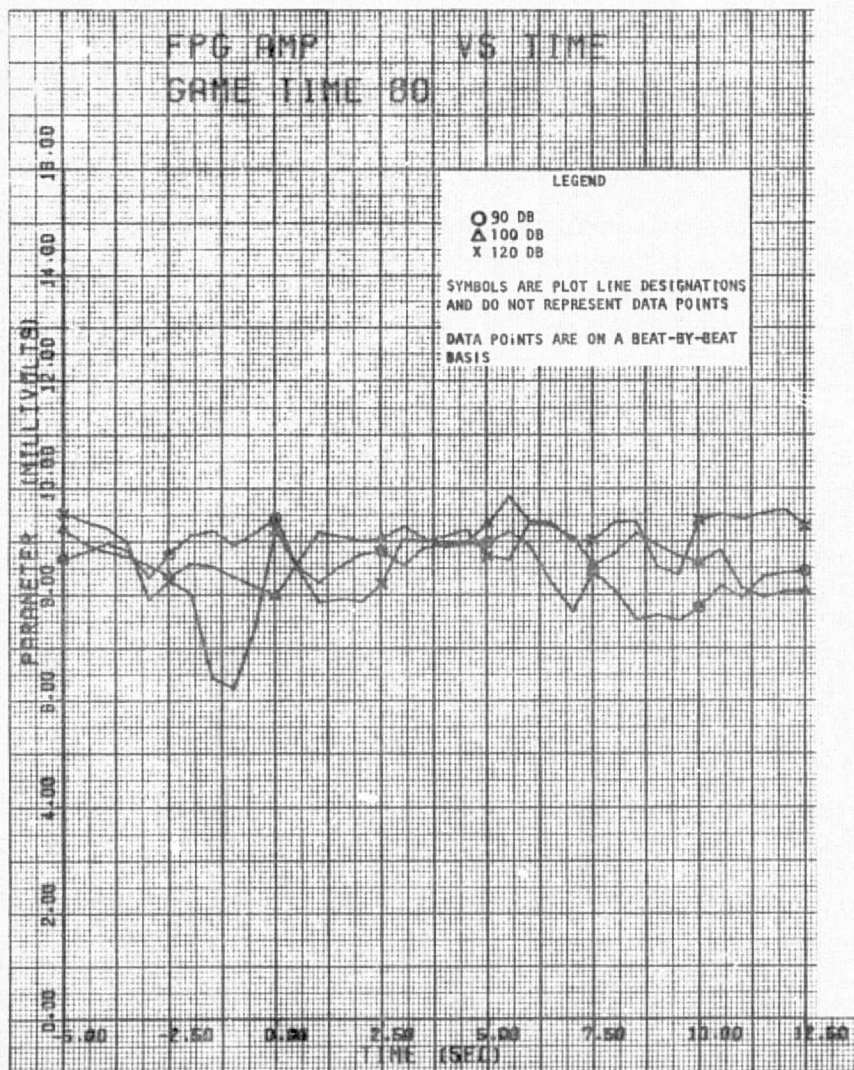
Figure 7-30. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --80-Sec Game Time
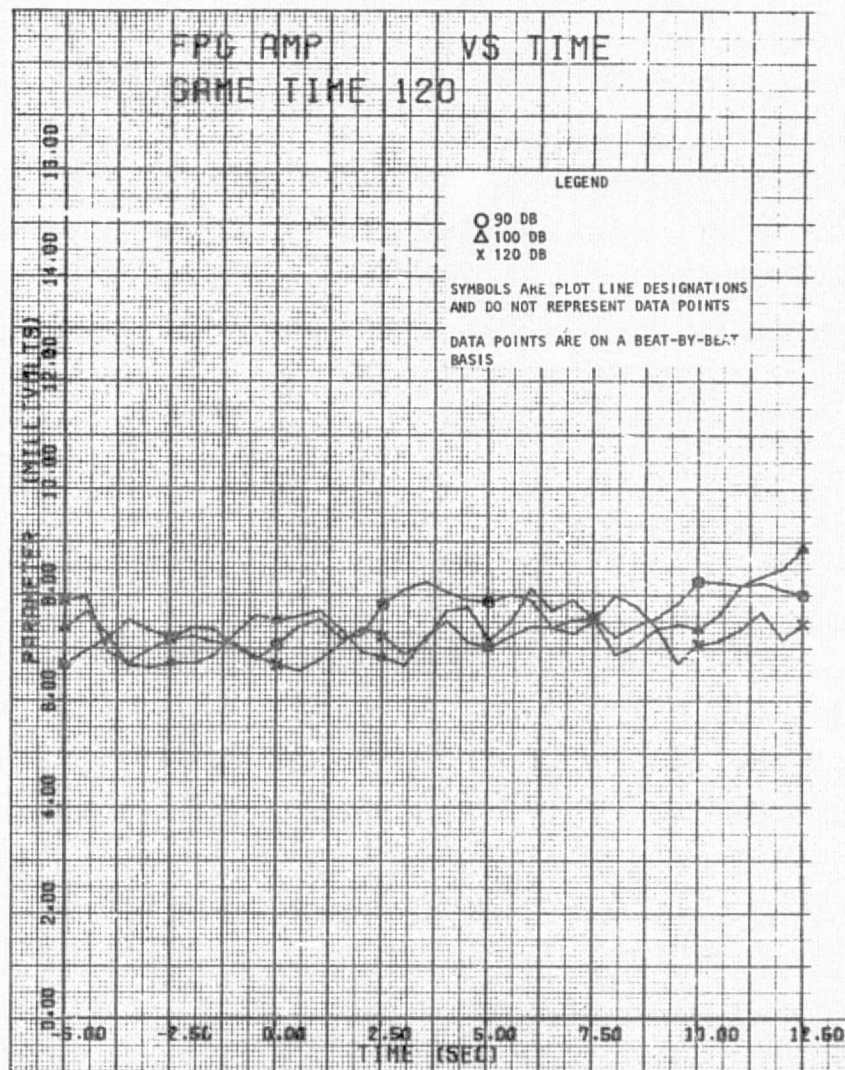
Figure 7-31. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --120-Sec Game Time
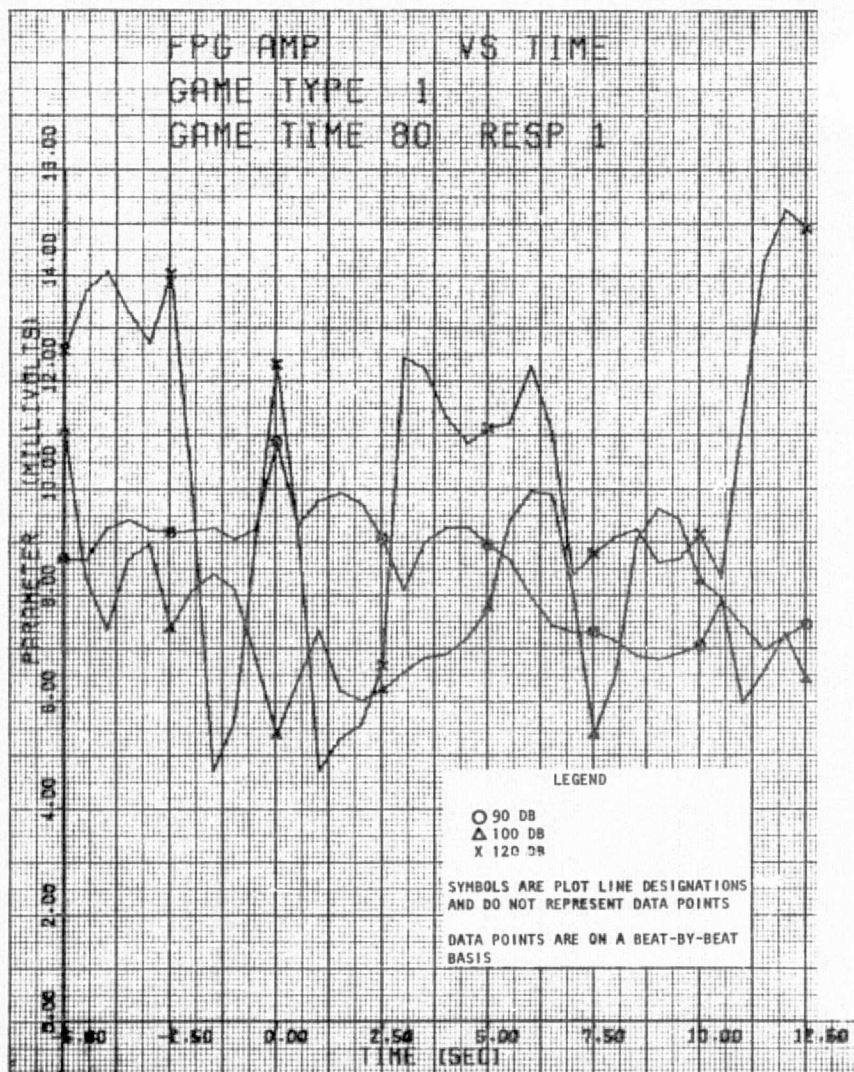
Figure 7-32.  FPG Pulse Amplitude for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 1, 80-Sec Game Time,
Response 1
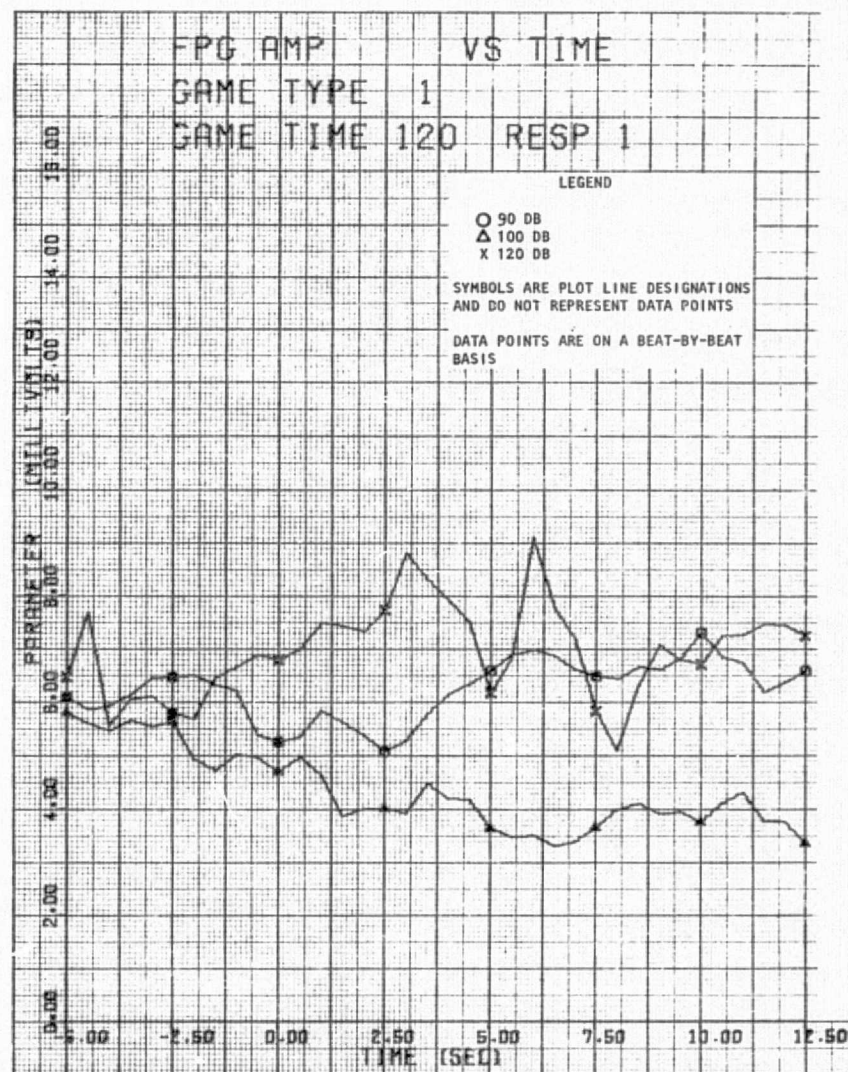
Figure 7-33.  FPG Pulse Amplitude for Test Day 3,
Conditions 5 and 6 (Less 110 db,
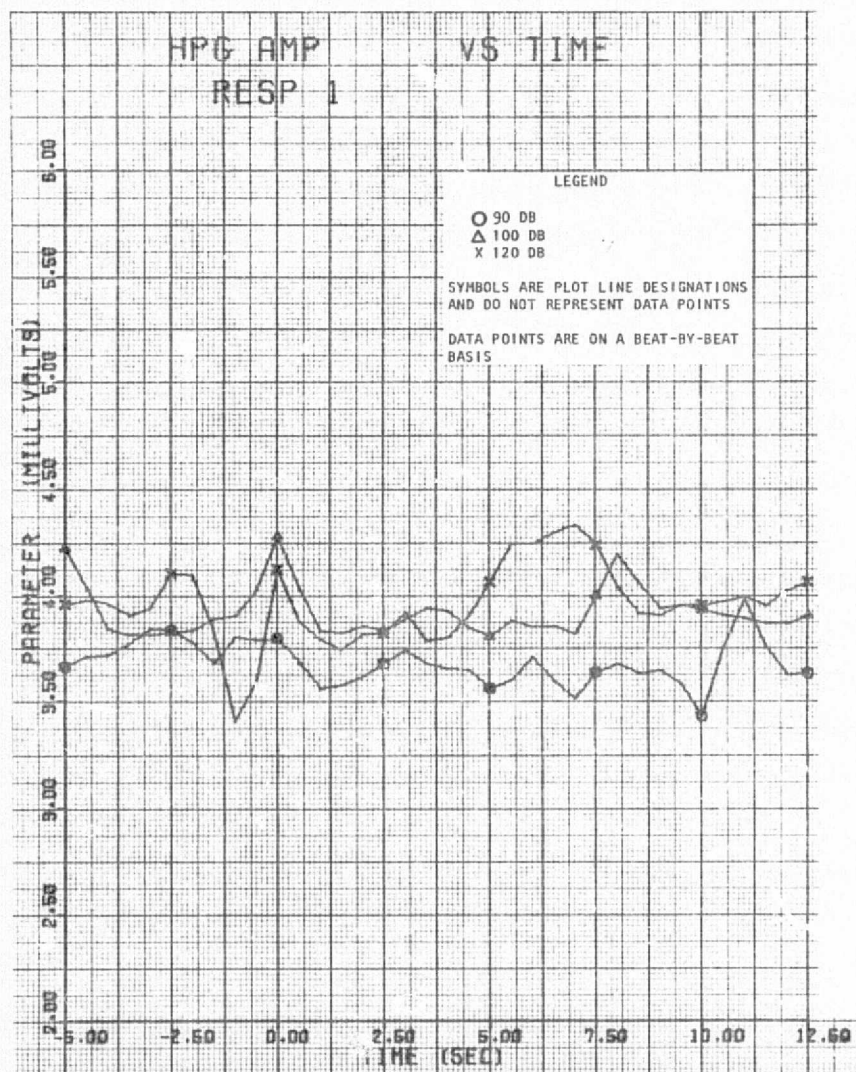100-Sec Task Duration, VM Task 3)
--Game Type 1, 120-Sec Game Time,
Response 1
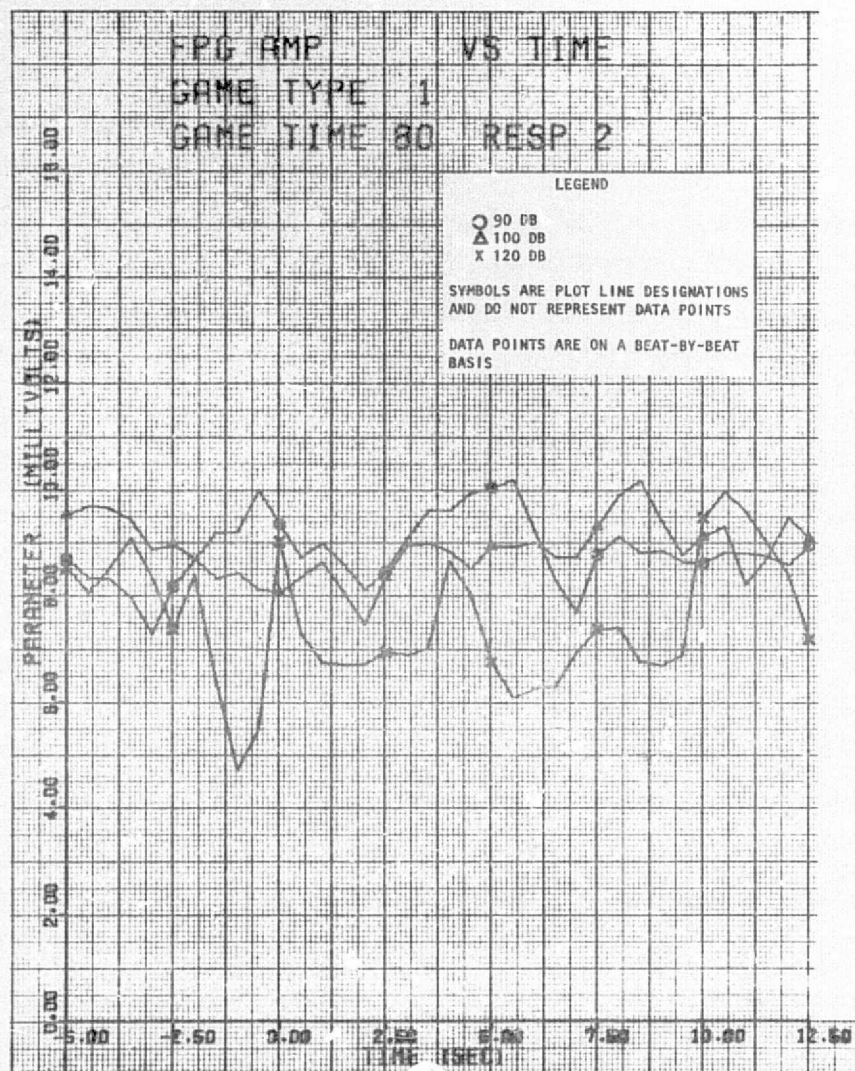
Figure 7-34. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 1, 80-Sec Game Time, Response 2
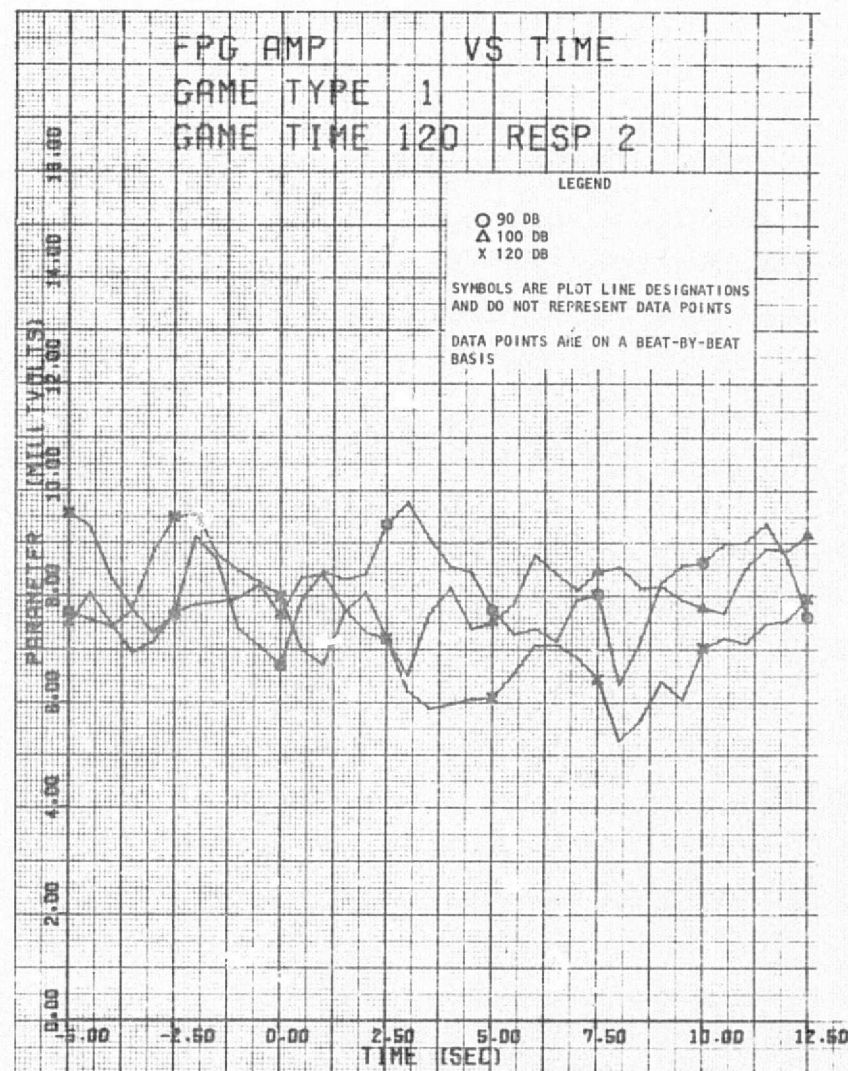


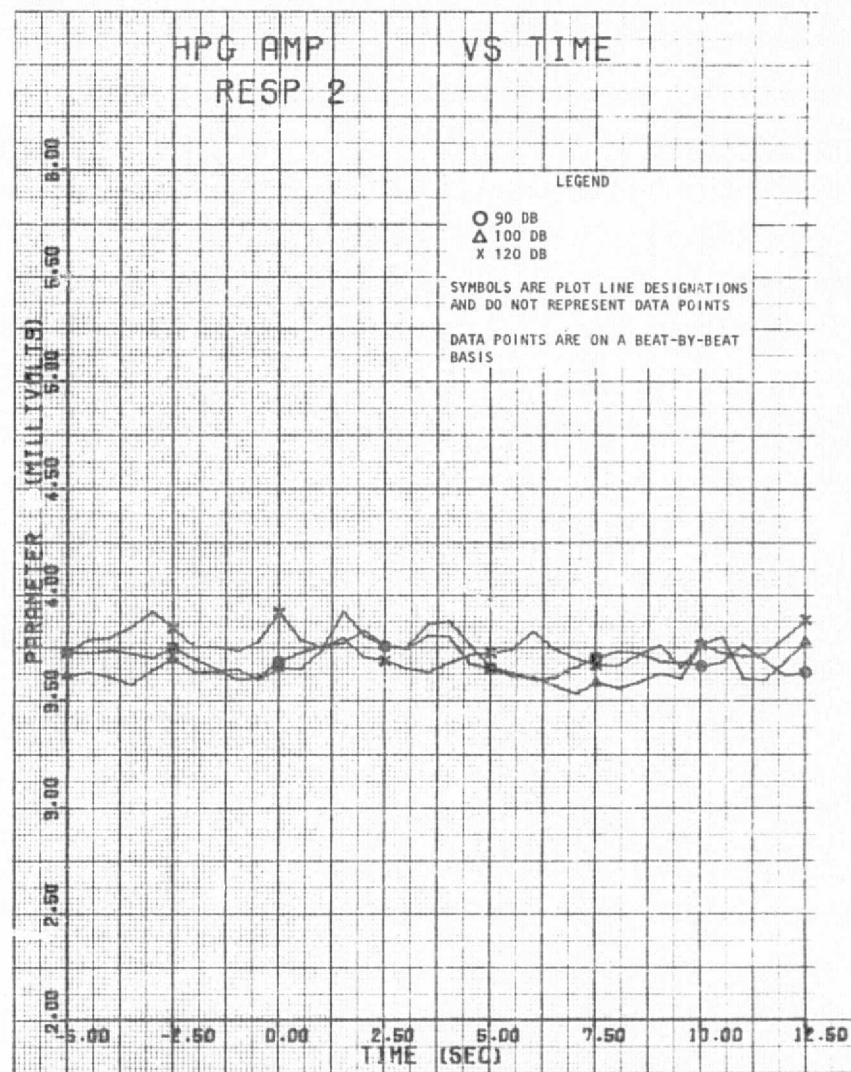Figure 7-35. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 1, 120-Sec Game Time, Response 2
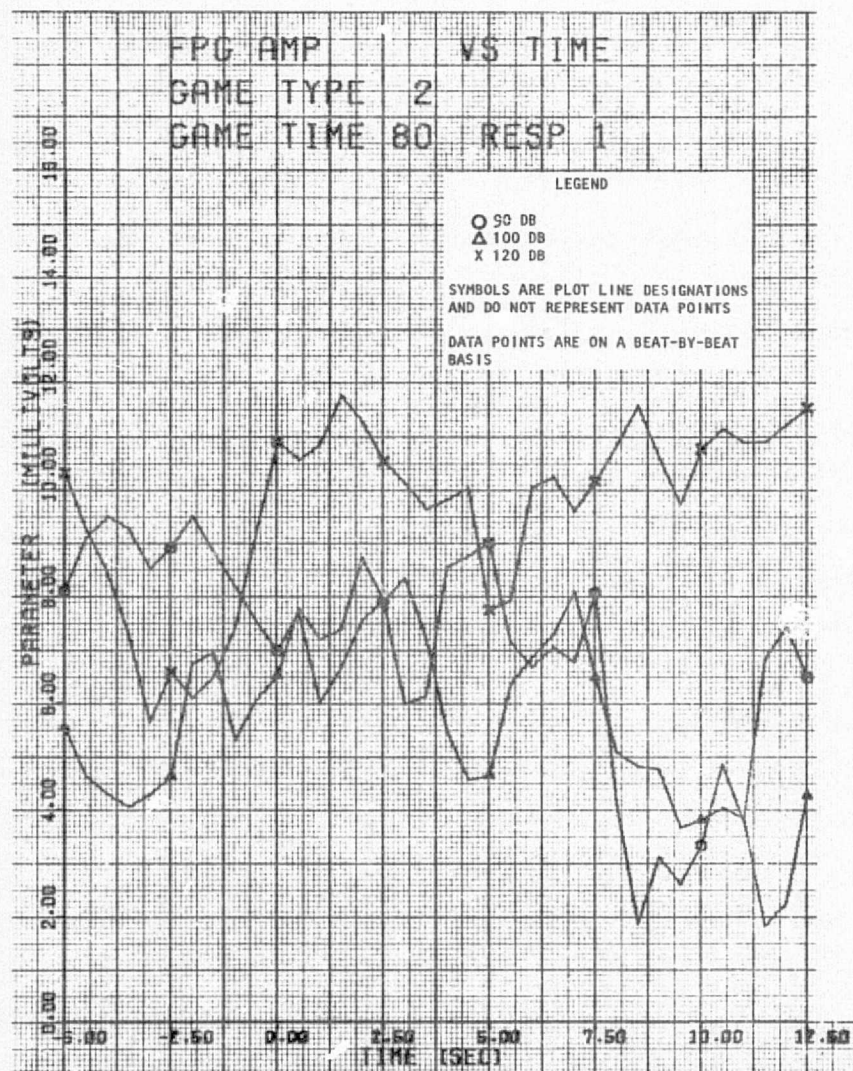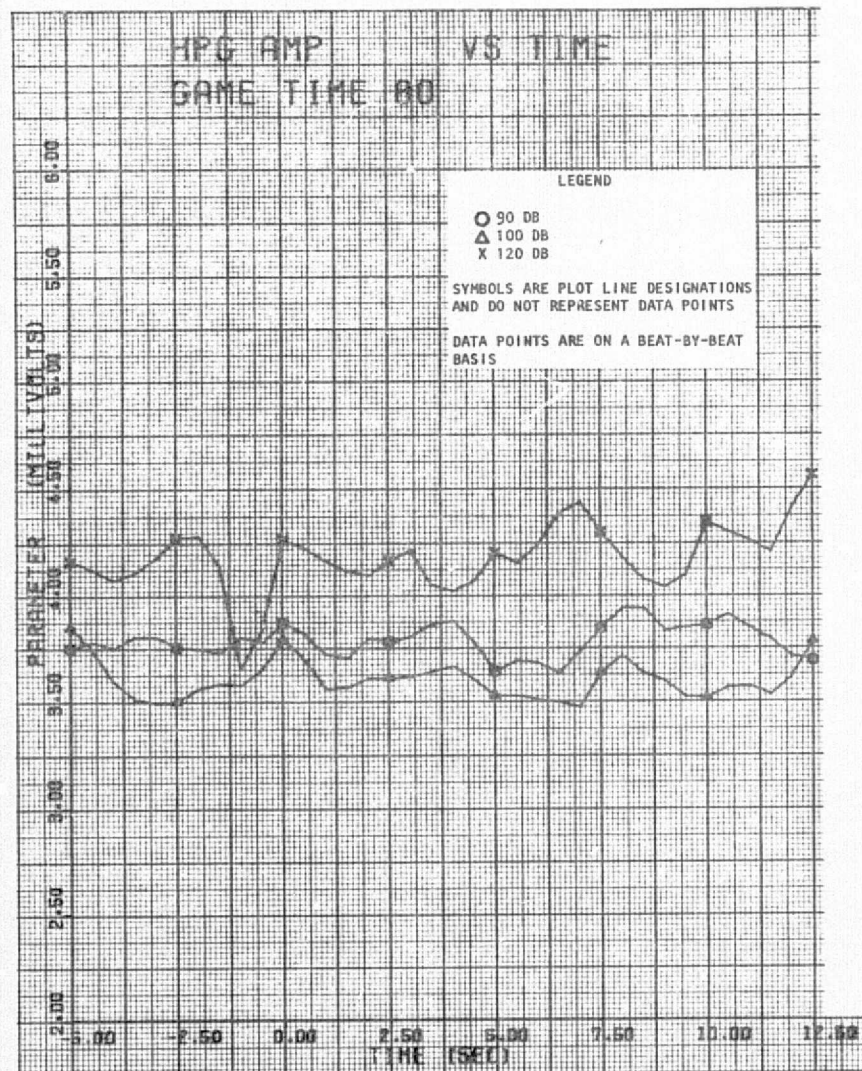
Figure 7-36. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 2, 80-Sec Game Time, Response 1
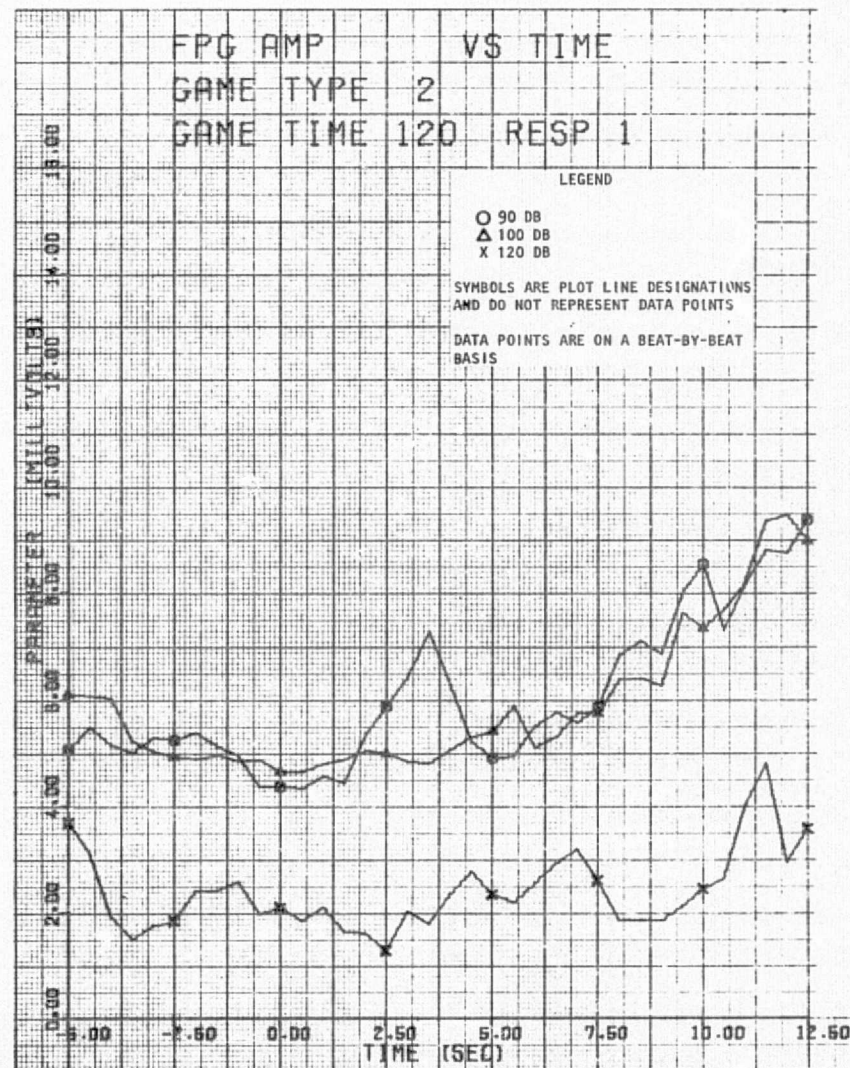


Figure 7-37. FPG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 2, 120-Sec Game Time, Response 1
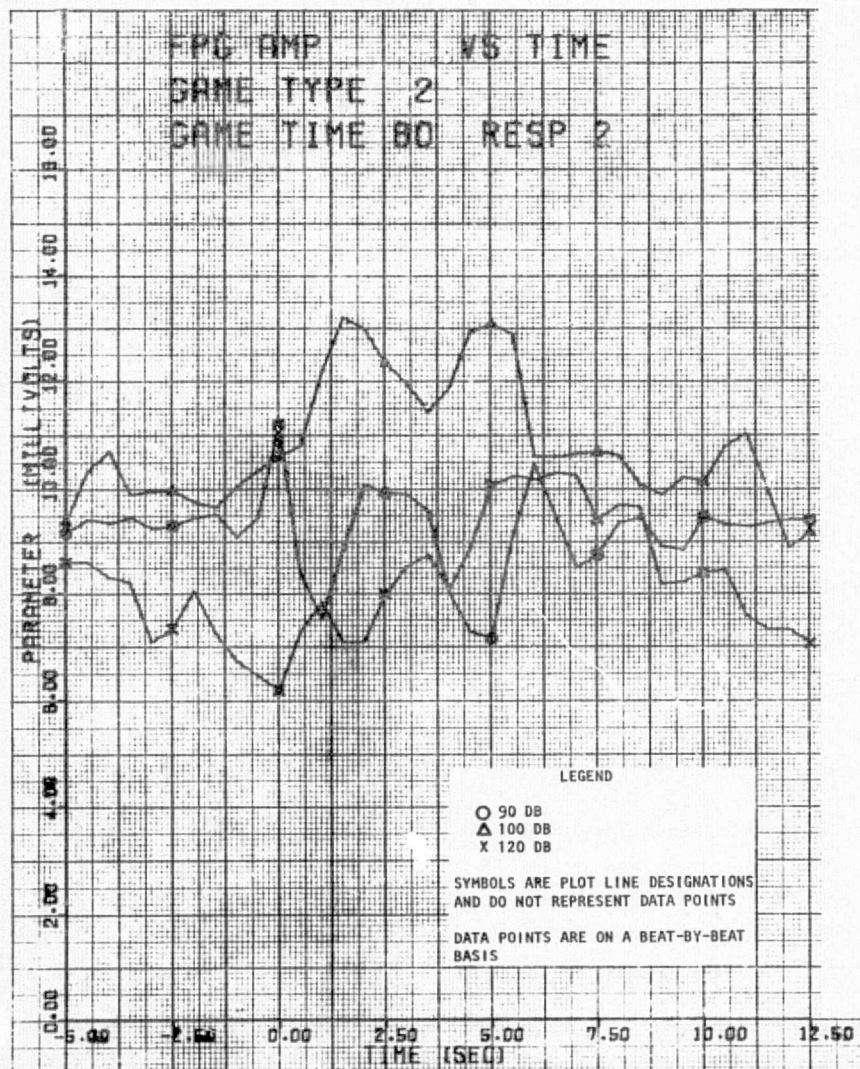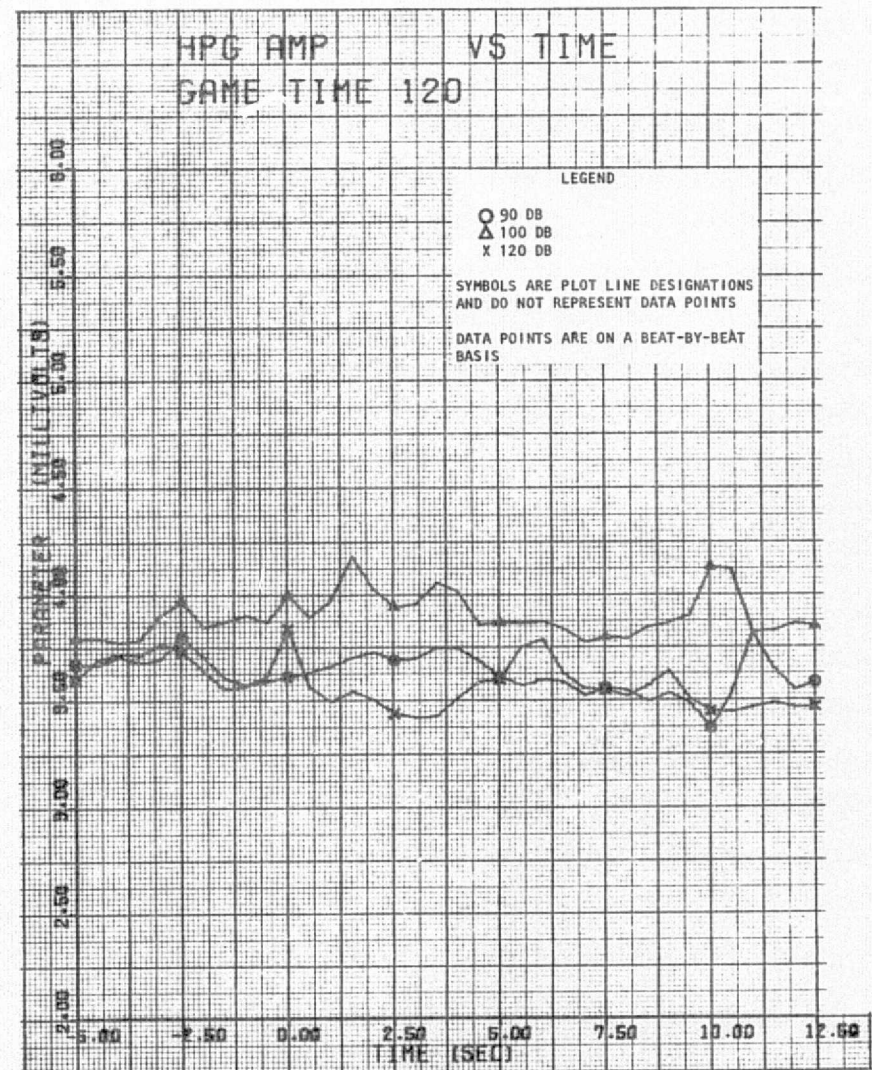
Figure 7-38.  FPG Pulse Amplitude for Test Day 3,
Conditions 5 and 6 (Less 110 db,
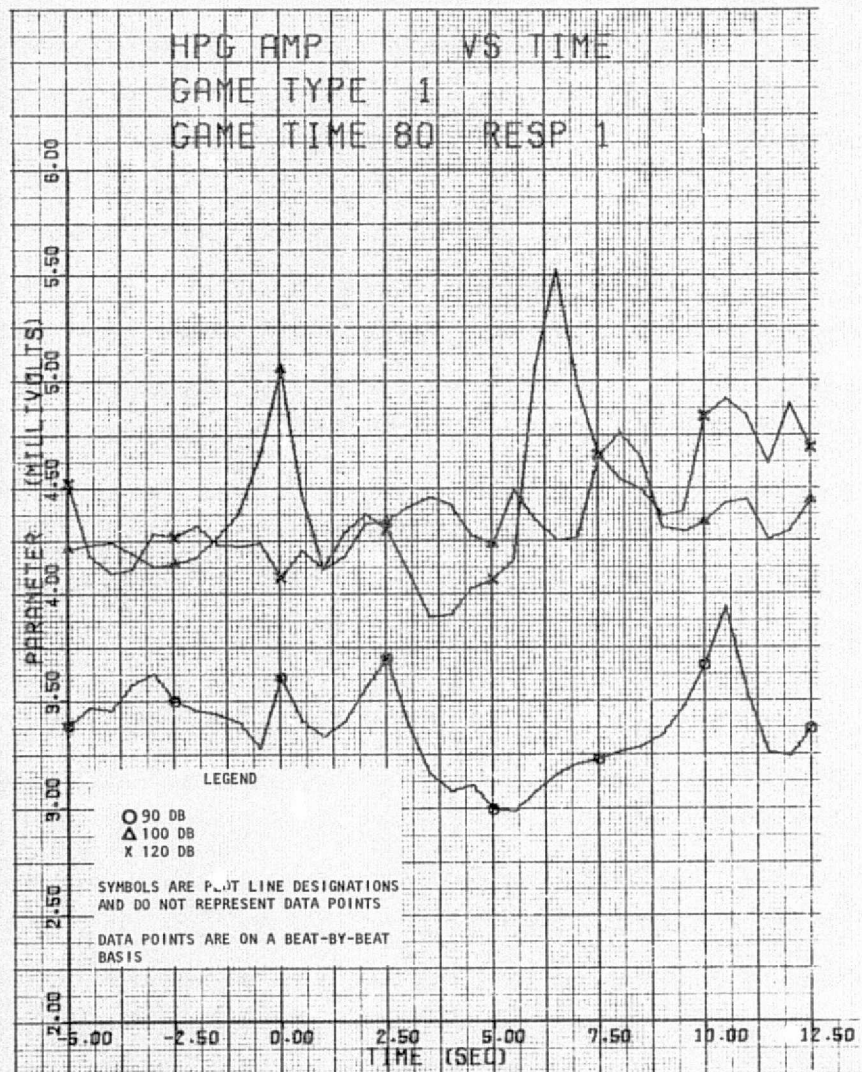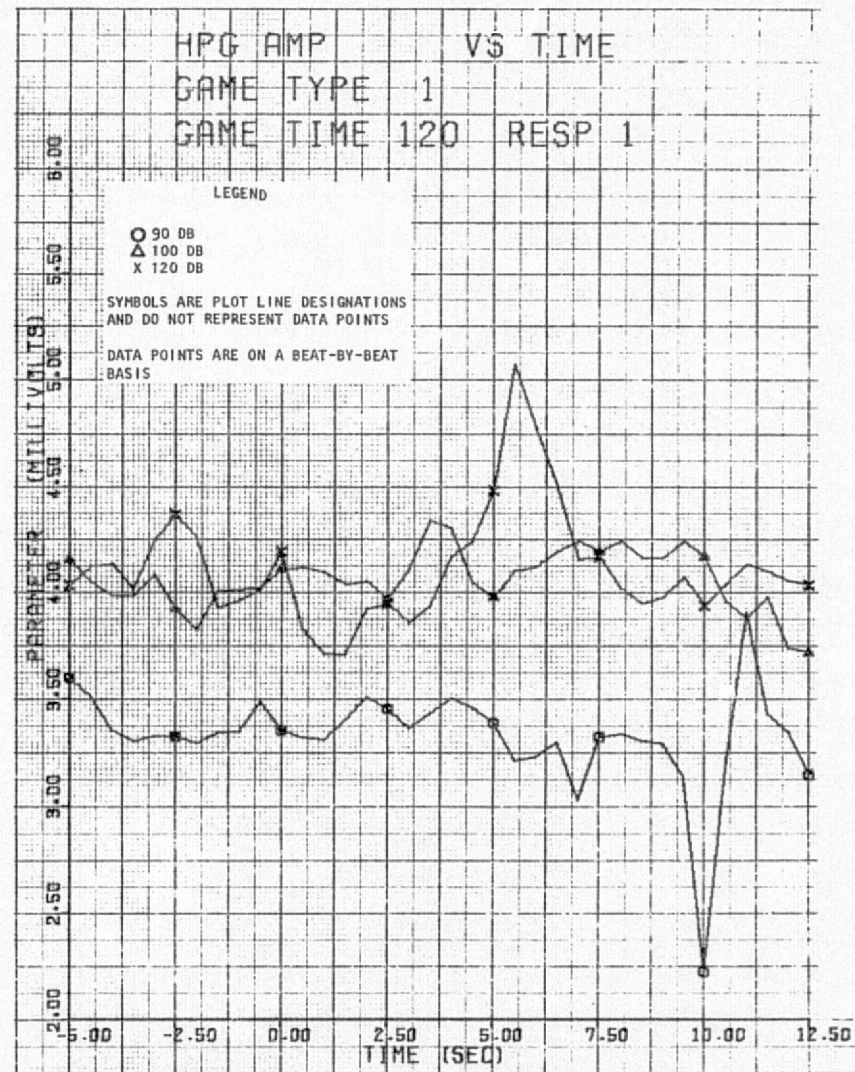100-Sec Task Duration, VM Task 3)
--Game Type 2, 80-Sec Game Time,
Response 2
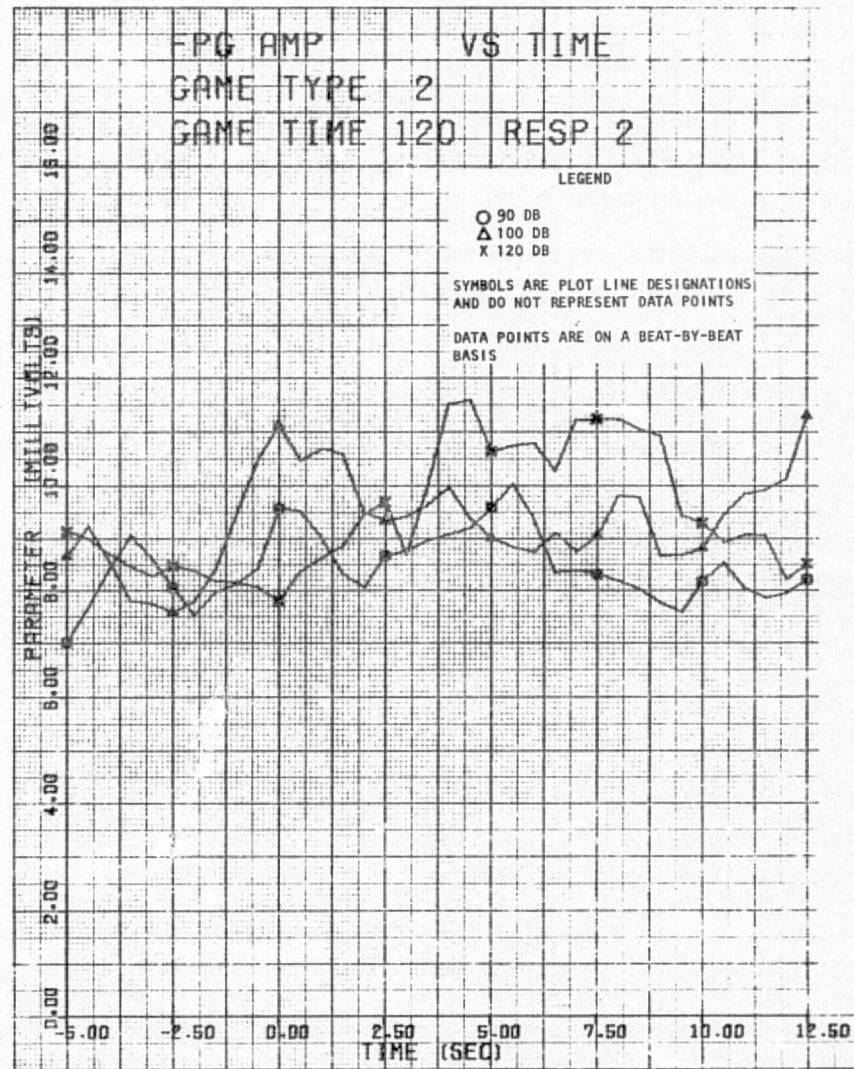


Figure 7-39.  FPG Pulse Amplitude for Test Day 3,
Conditions 5 and 6 (Less 110 db,
100-Sec Task Duration, VM Task 3)
--Game Type 2, 120-Sec Game Time
Response 2

Figure 7-40. Elapsed Time from ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task
Duration, VM Task 3)

Figure 7-41. Elapsed Time from ECG to FPG
for Test Day 3, Conditions 5
and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)
--Game Type 1

Figure 7-42. Elapsed Time from ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task
Duration, VM Task 3)--Game Type 2

Figure 7-43.  Elapsed Time form ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task
Duration, VM Task 3)--Response 1



Figure 7-44.  Elapsed Time from ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task Duration,
VM Task 3)--Response 2
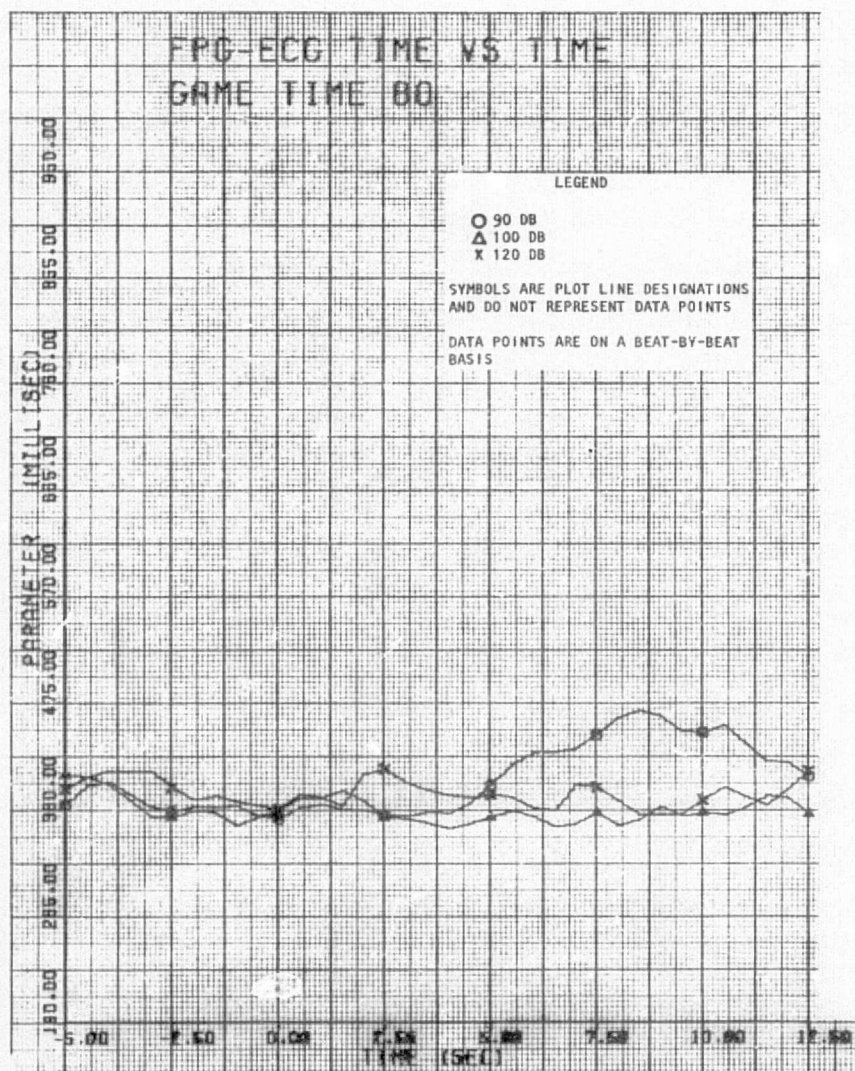
Figure 7-45. Elapsed Time from ECG to FPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--80-Sec Game Time
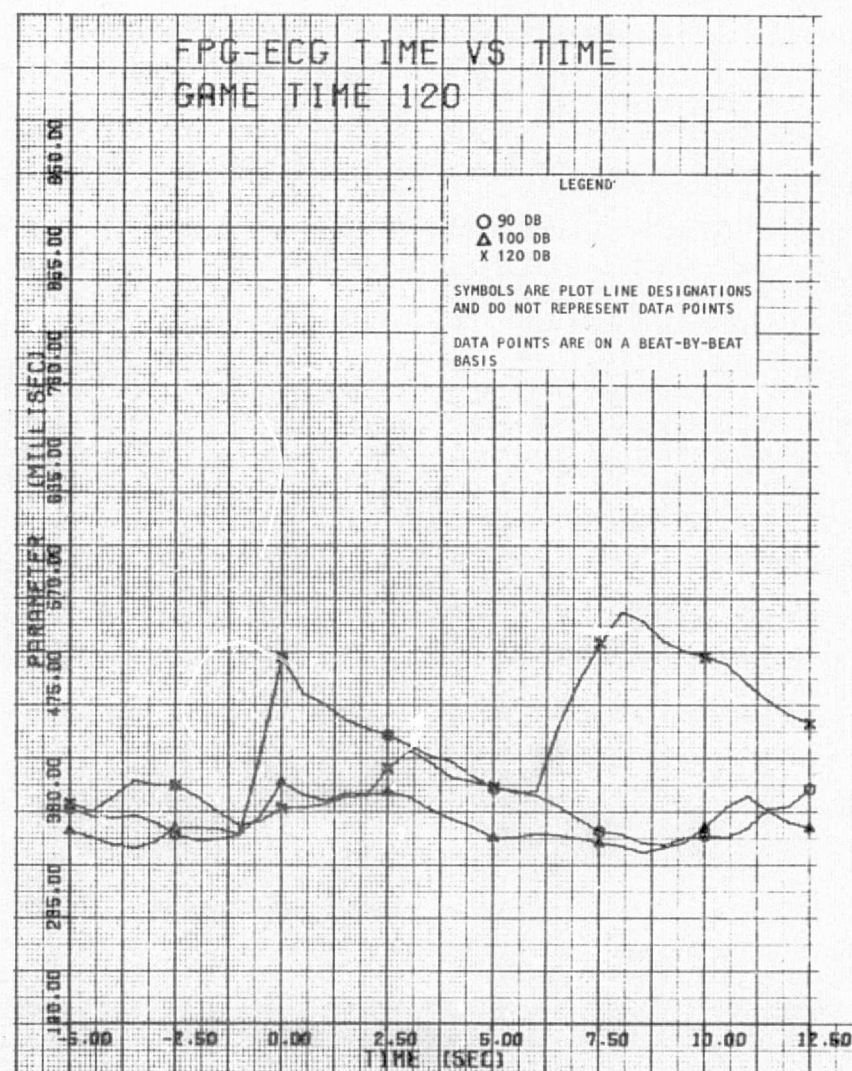


Figure 7-46. Elapsed Time from ECG to FPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--120-Sec Game Time
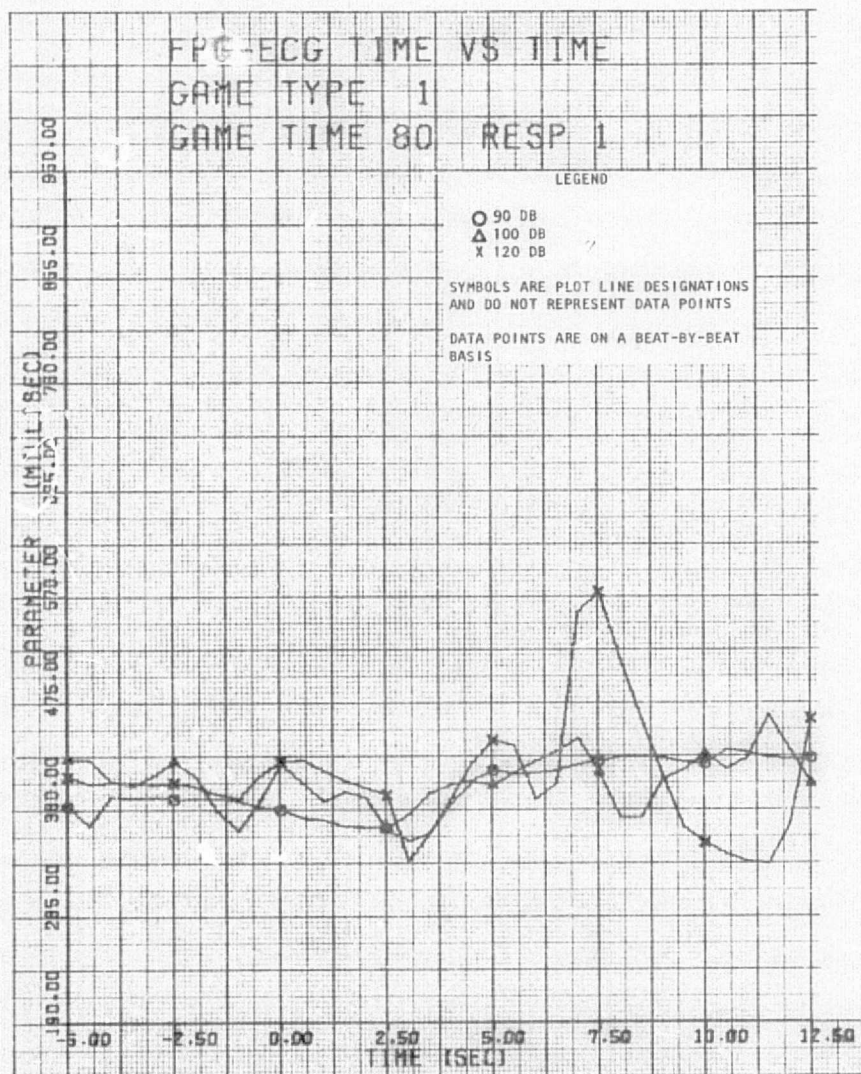
Figure 7-47. Elapsed Time from ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task Duration,
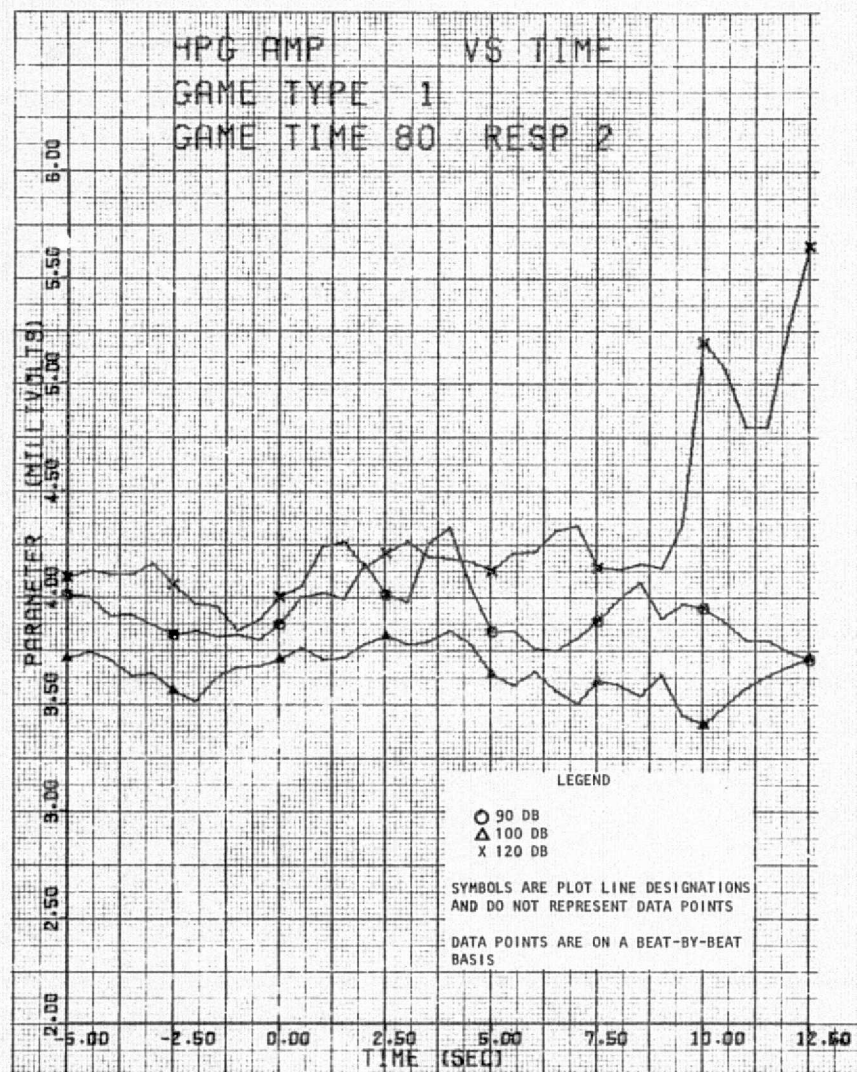VM Task 3)--Game Type 1,
80-Sec Game Time, Response 1
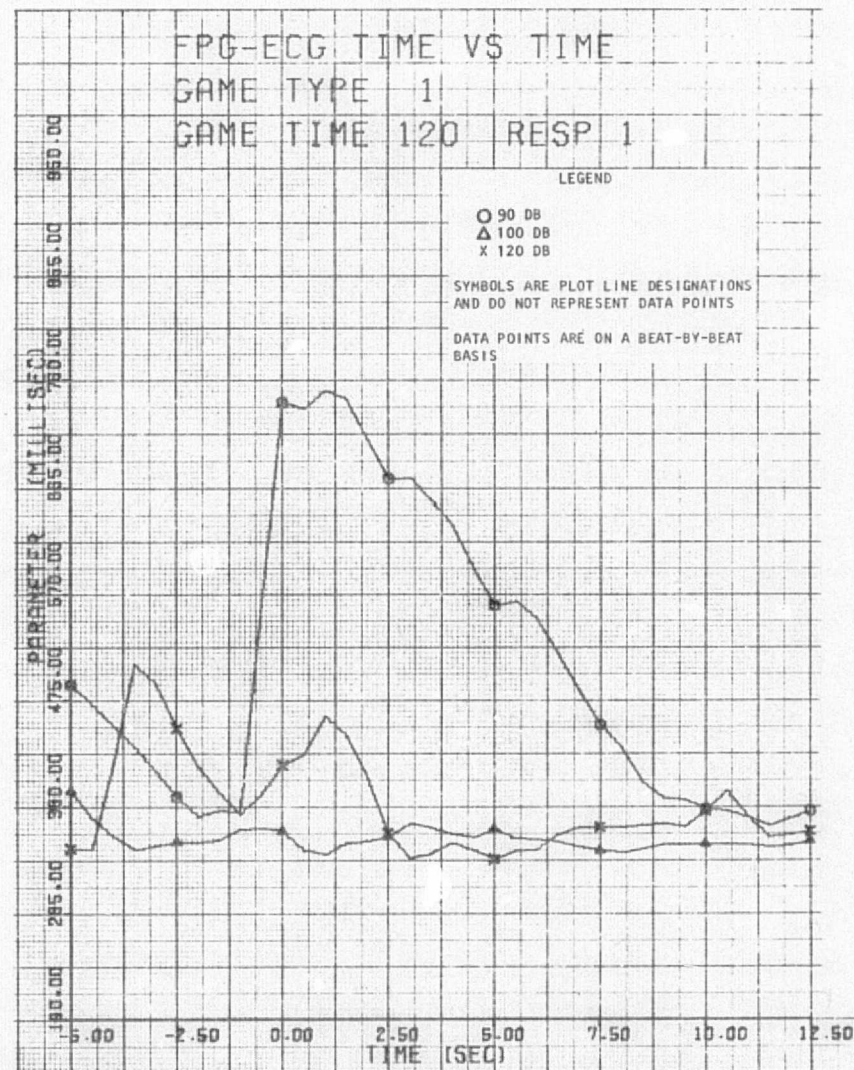


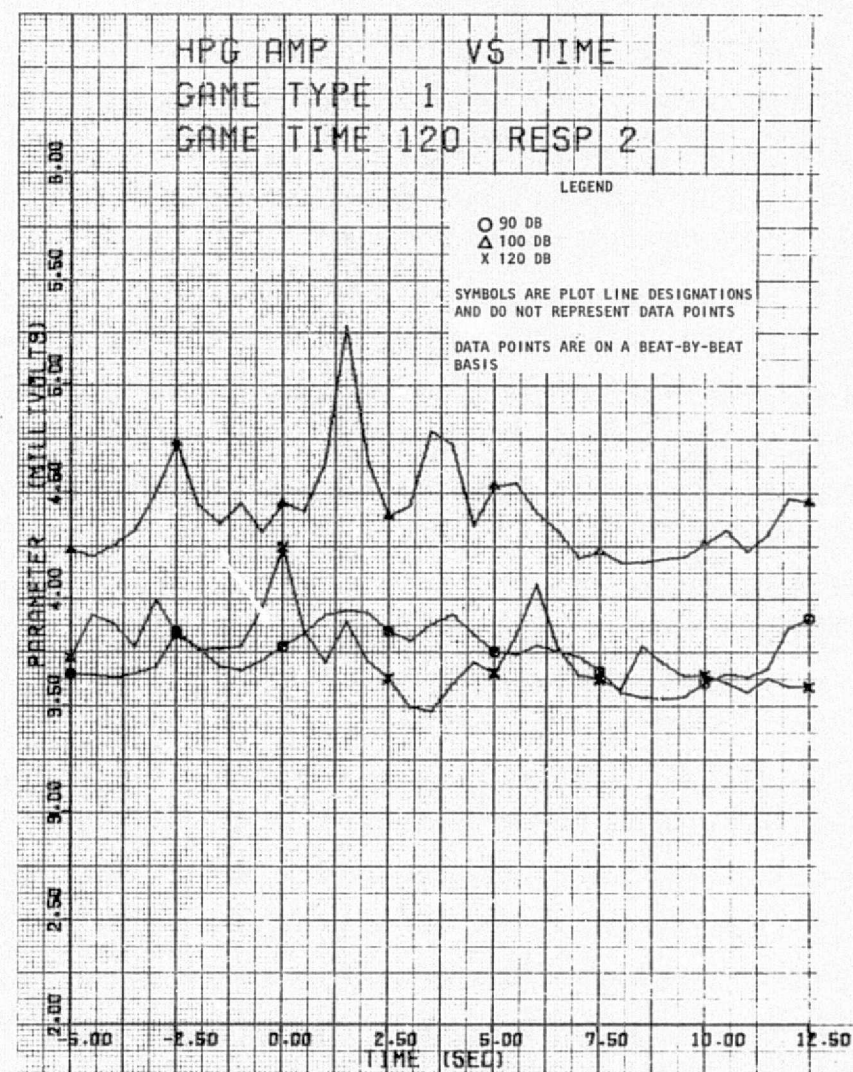Figure 7-48. Elapsed Time from ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task Duration,
VM Task 3)--Game Type 1, 120-Sec
Game Time, Response 1

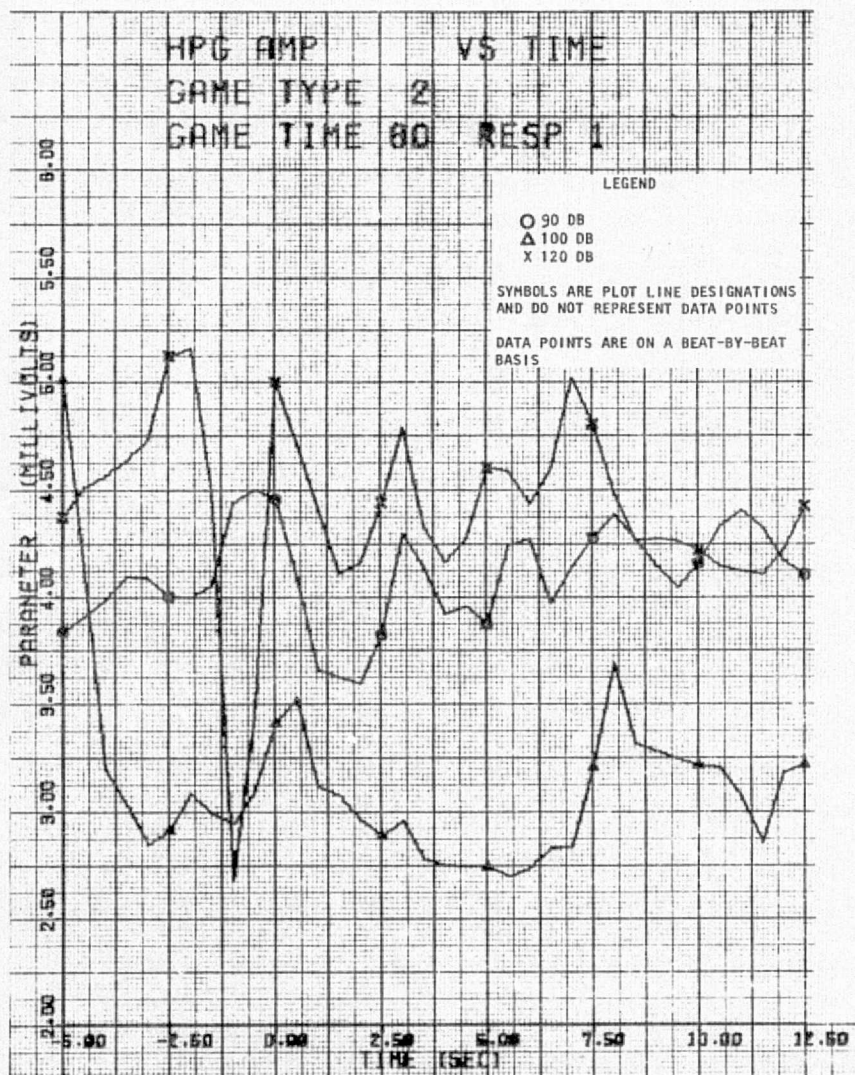Figure 7-49. Elapsed Time from ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task Duration,
VM Task 3)--Game Type 1,
80-Sec Game Time, Response 2



Figure 7-50. Elapsed Time from ECG to FPG for
Test Day 3, Conditions 5 and 6
(Less 110 db, 100-Sec Task Duration,
VM Task 3)--Game Type 1, 120-Sec
Game Time, Response 2

Figure 7-51. Elapsed Time from ECG to FPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 1



Figure 7-52. Elapsed Time from ECG to FPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 1
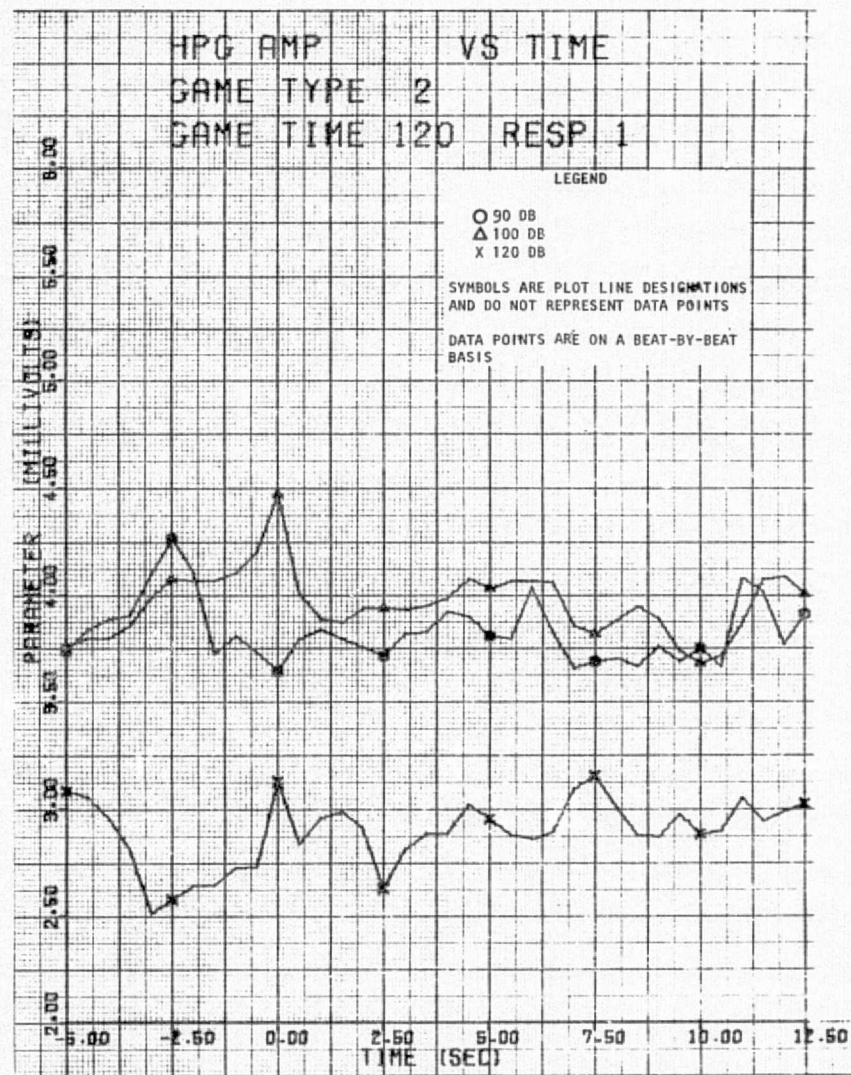
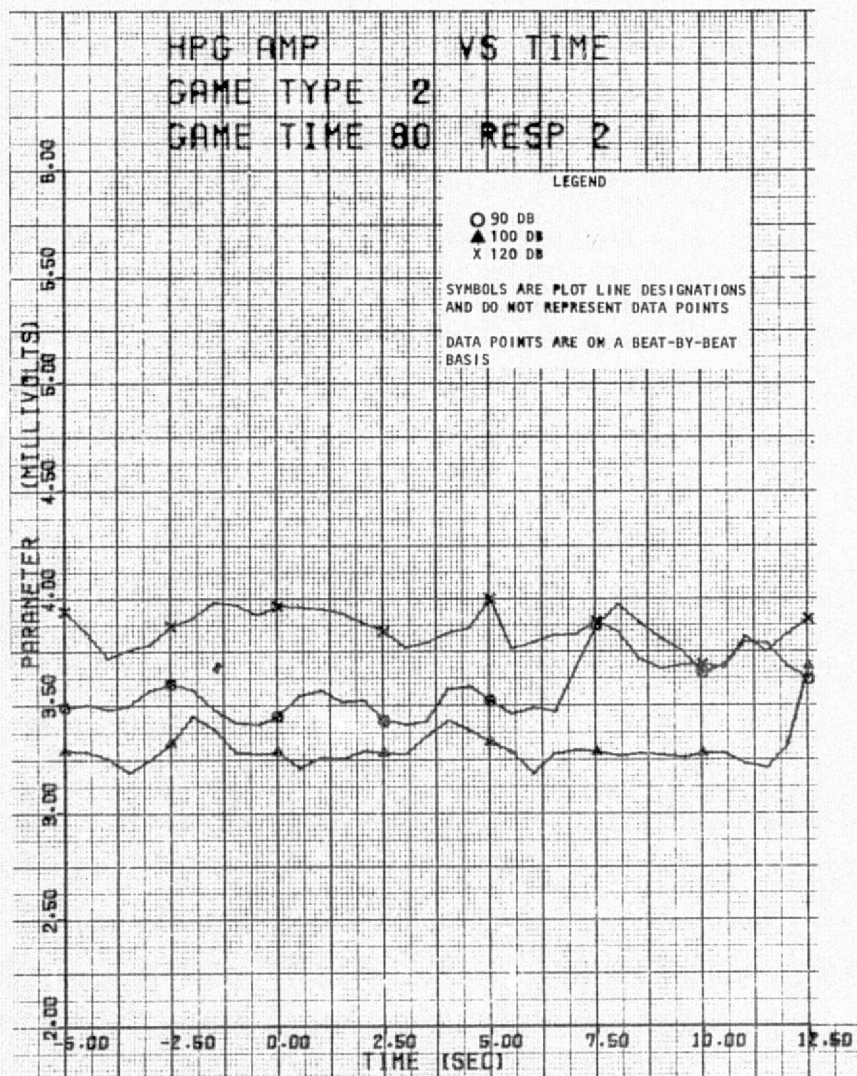Figure 7-53.  Elapsed Time from ECG to FPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 2



Figure 7-54.  Elapsed Time from ECG to FPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 2

Figure 7-55. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)
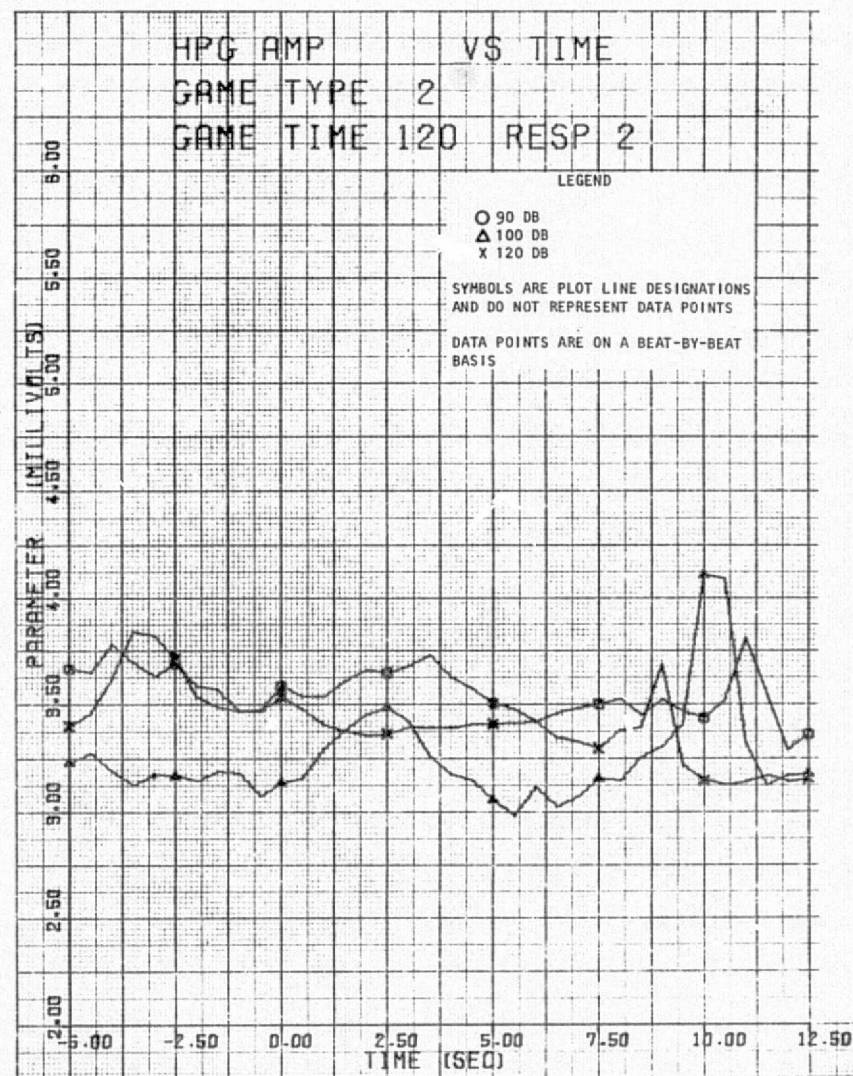
Figure 7-56. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1



Figure 7-57. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2

Figure 7-58.   HPG Pulse Amplitude as a Function of
Time for Test Day 3, Conditions 5
and 6 (Less 110 db, 100-Sec Task
Duration, VM Task 3)--Response 1



Figure 7-59.   HPG Pulse Amplitude as a Function
of Time for Test Day 3, Conditions 5
and 6 (Less 110 db, 100-Sec Task
Duration, VM Task 3)--Response 2

Figure 7-60.   HPG Pulse Amplitude as a Function
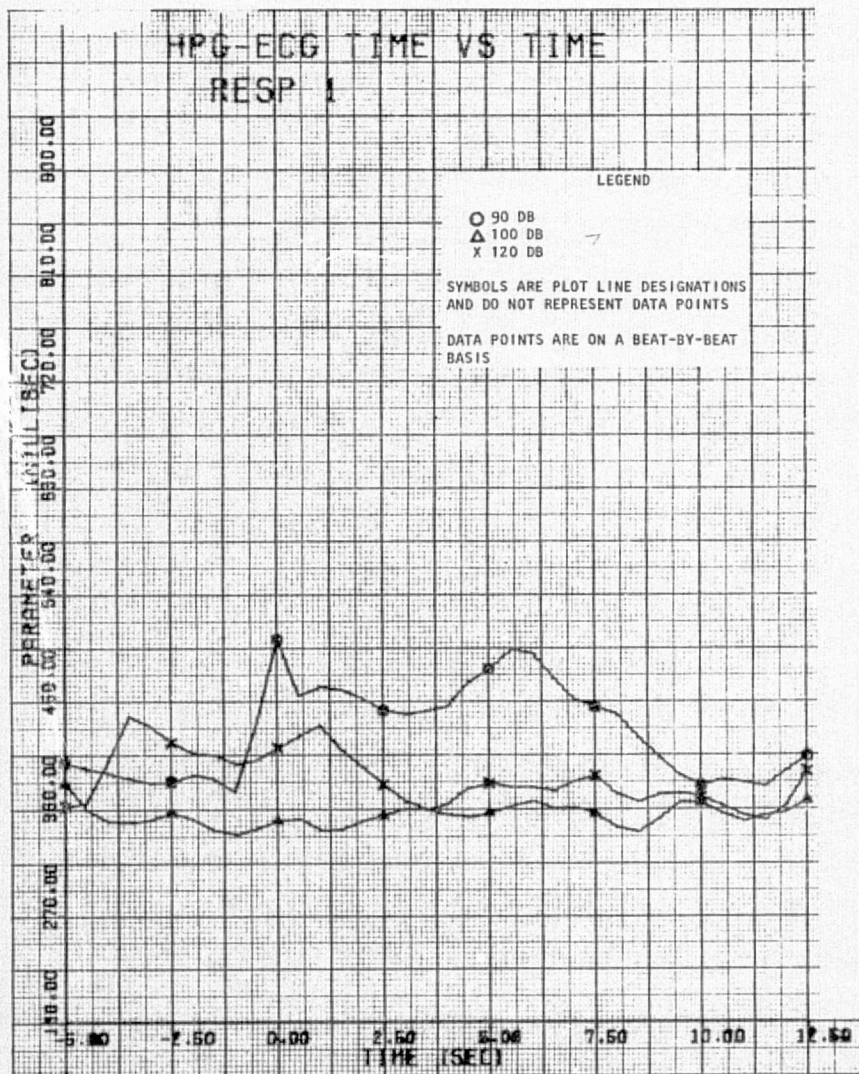of Time for Test Day 3, Conditions 5
and 6 (Less 110 db, 100-Sec Task Duration
VM Task 3)--80-Sec Game Time



Figure 7-61.   HPG Pulse Amplitude as a Function of
Time for Test Day 3, Conditions 5 and
6 (Less 110 db, 100-Sec Task Duration,
VM Task 3)--120-Sec Game Time

Figure 7-62. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 1, 80-Sec Game Time, Response 1



Figure 7-63. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 1, 120-Sec Game Time, Response 1

Figure 7-64. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 1, 80-Sec Game Time, Response 2



Figure 7-65. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 1, 120-Sec Game Time, Response 2

Figure 7-66. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 2, 80-Sec Game Time, Response 1



Figure 7-67. HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3) --Game Type 2, 120-Sec Game Time, Response 1

Figure 7-68.  HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 2

Figure 7-69.  HPG Pulse Amplitude as a Function of Time for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 2
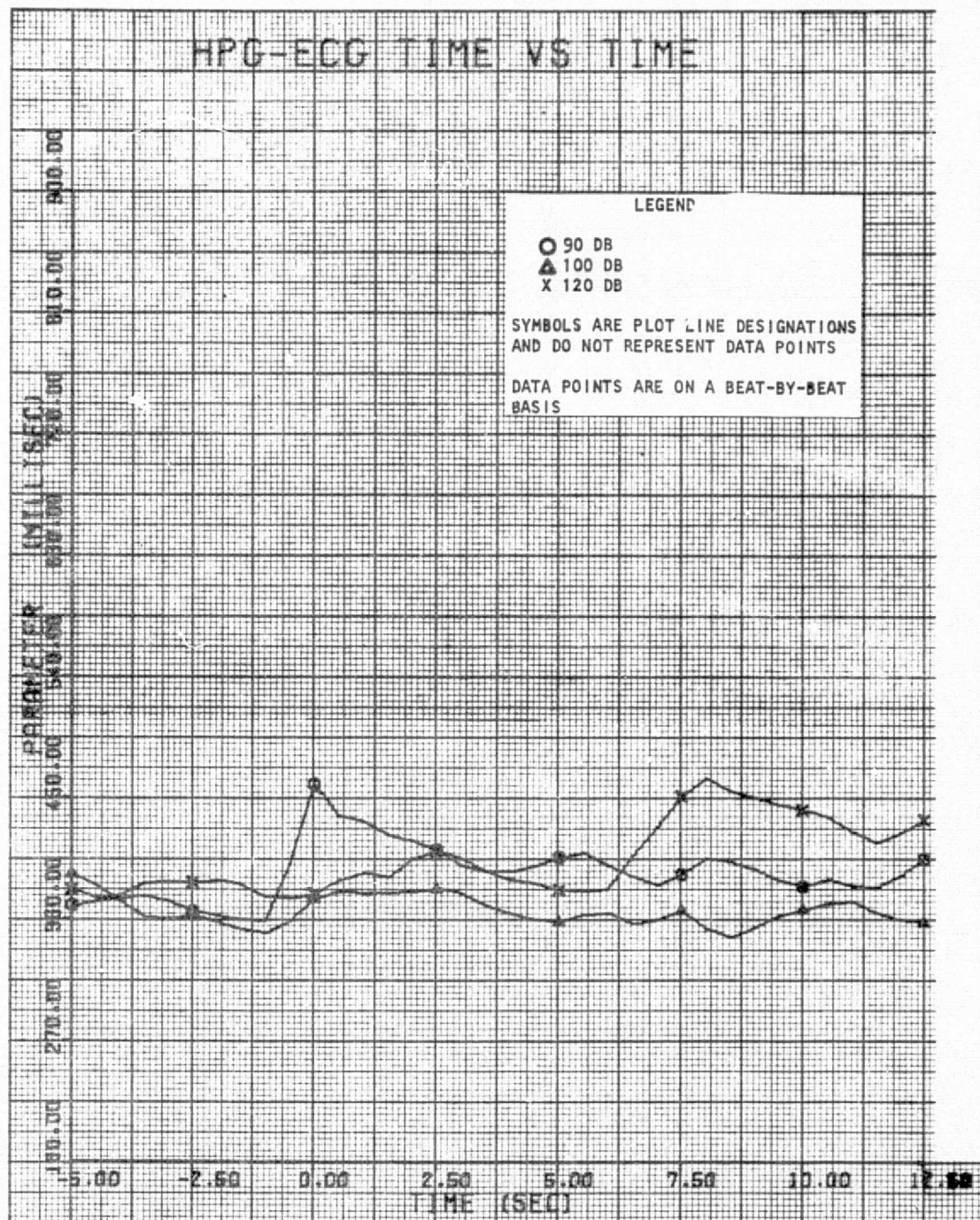
Figure 7-70. Elapsed Time from ECG to HPG for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec Task
Duration, VM Task 3)
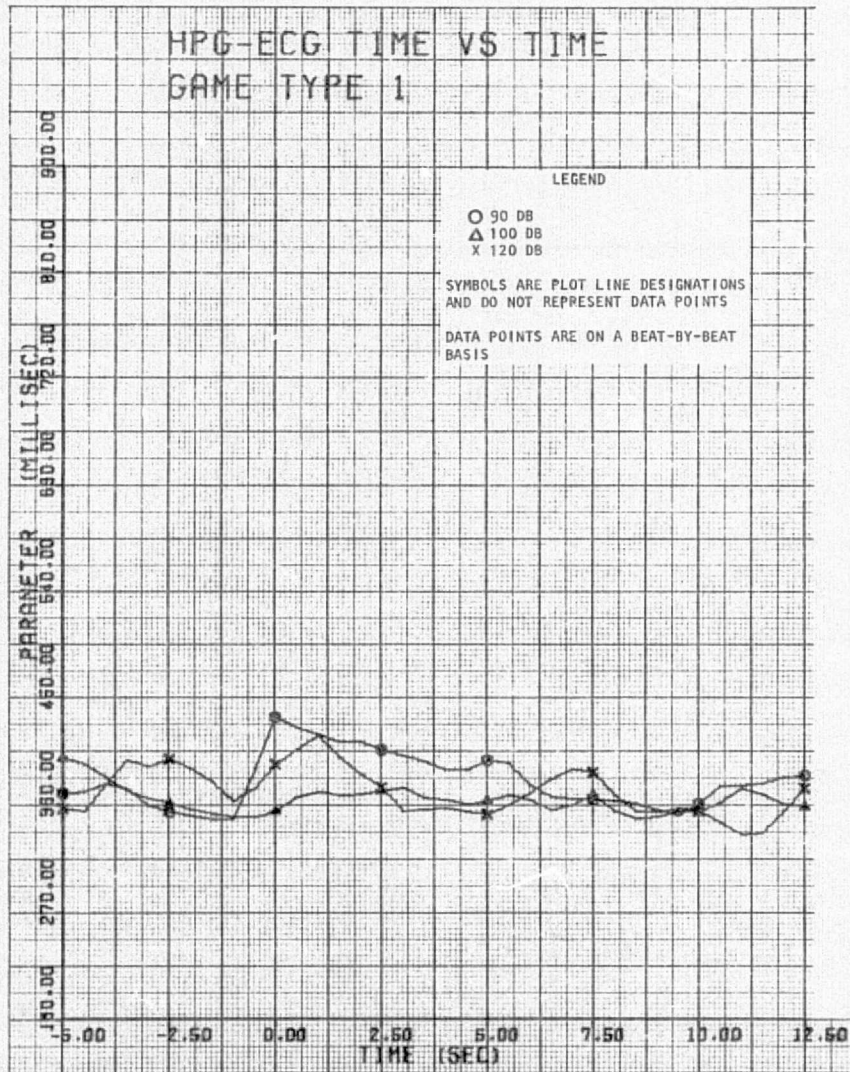
Figure 7-71.  Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1
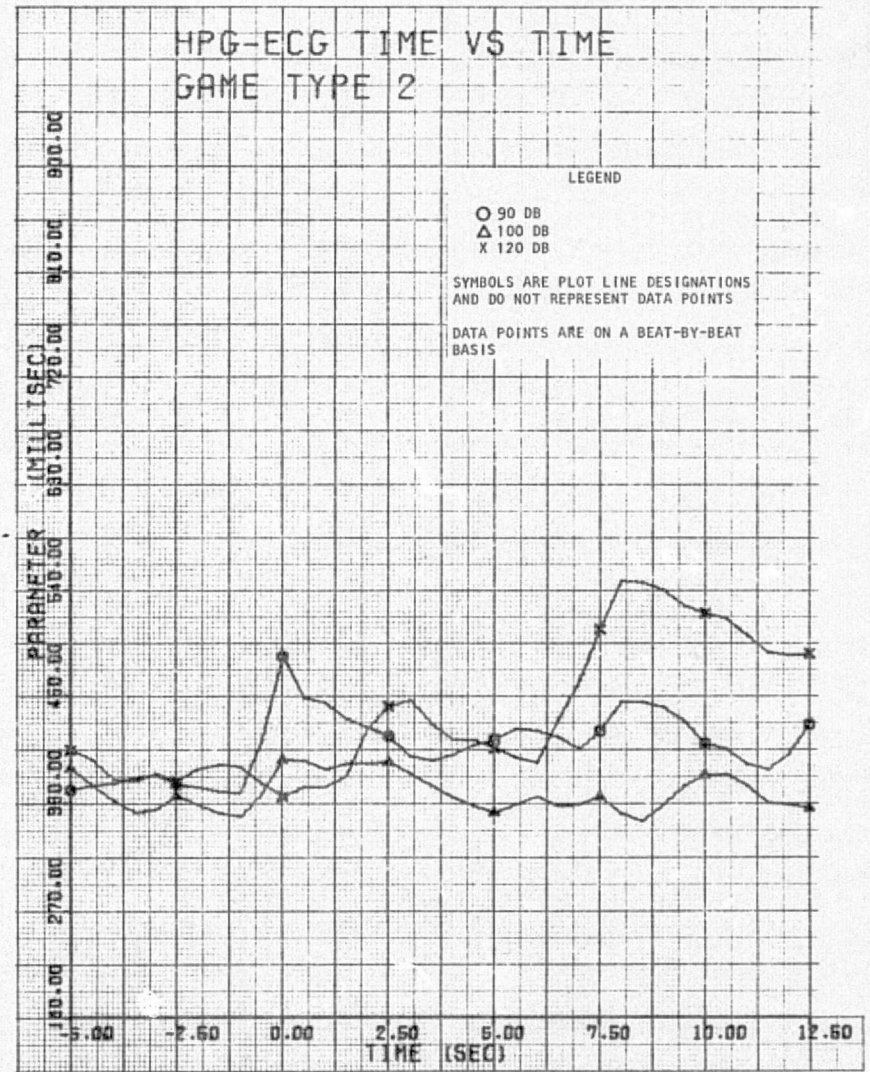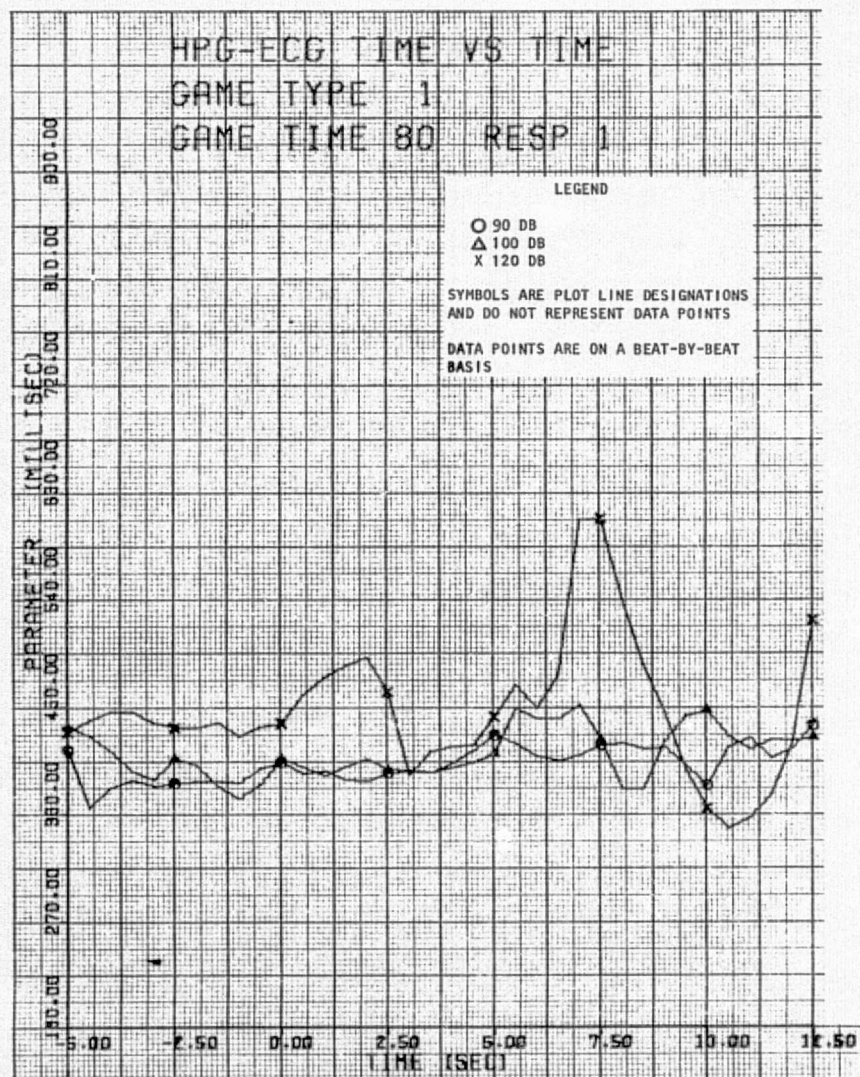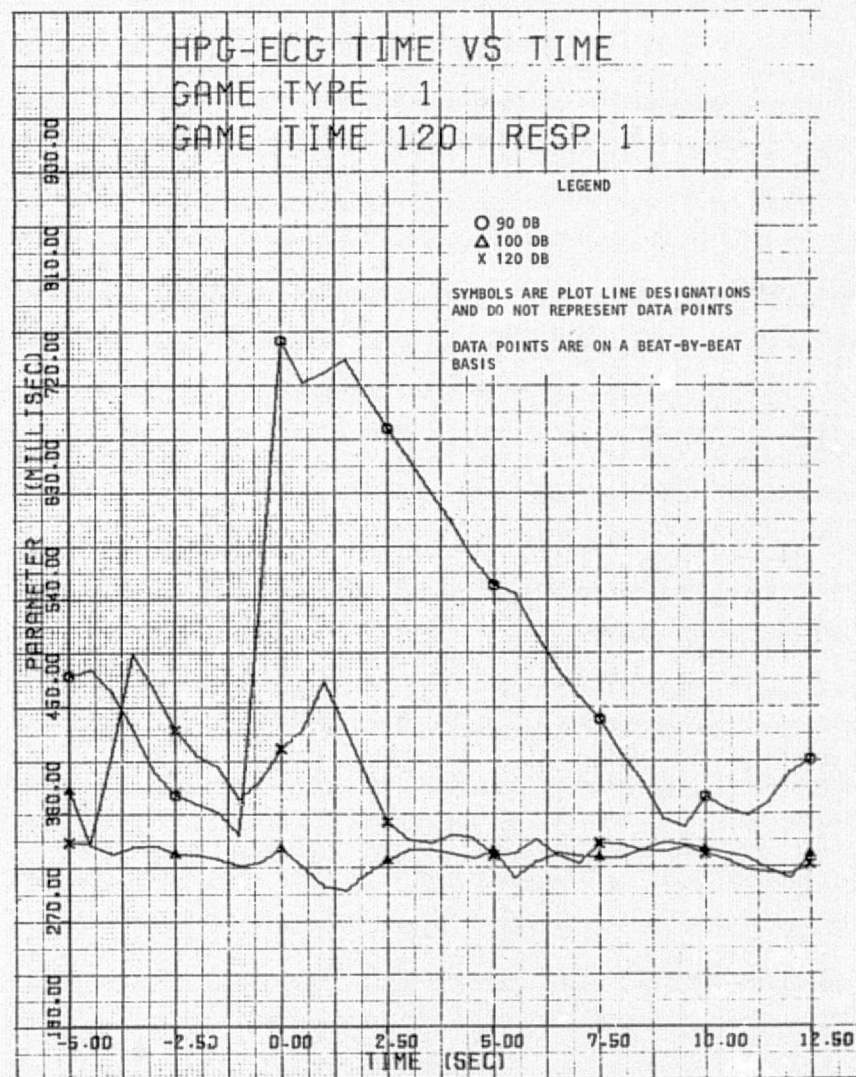
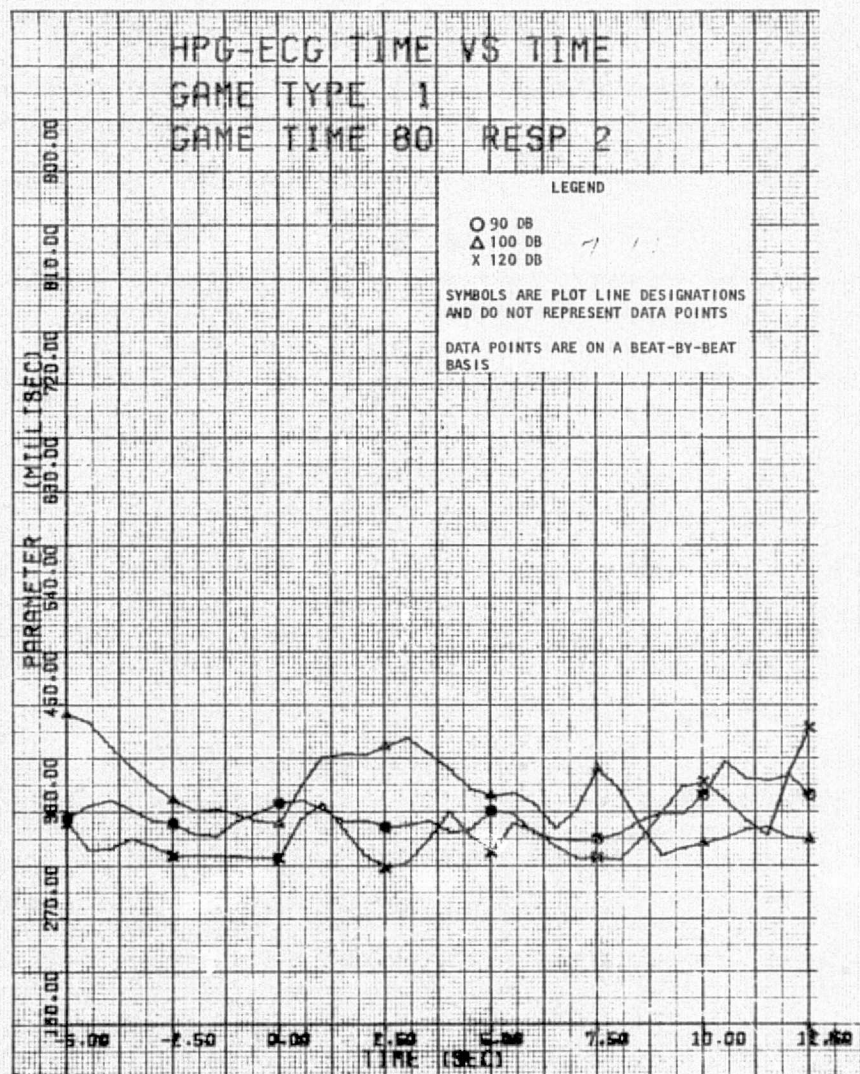Figure 7-72.  Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 3

Figure 7-73. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 1
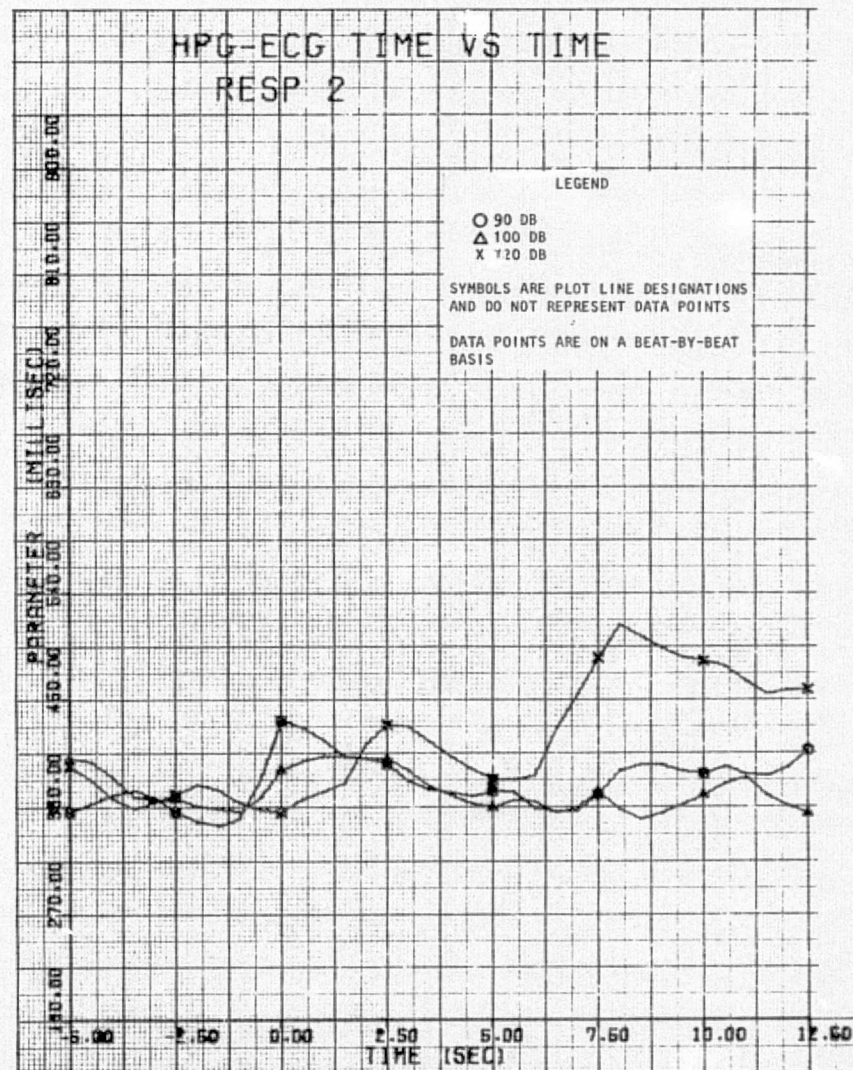


Figure 7-74. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 2
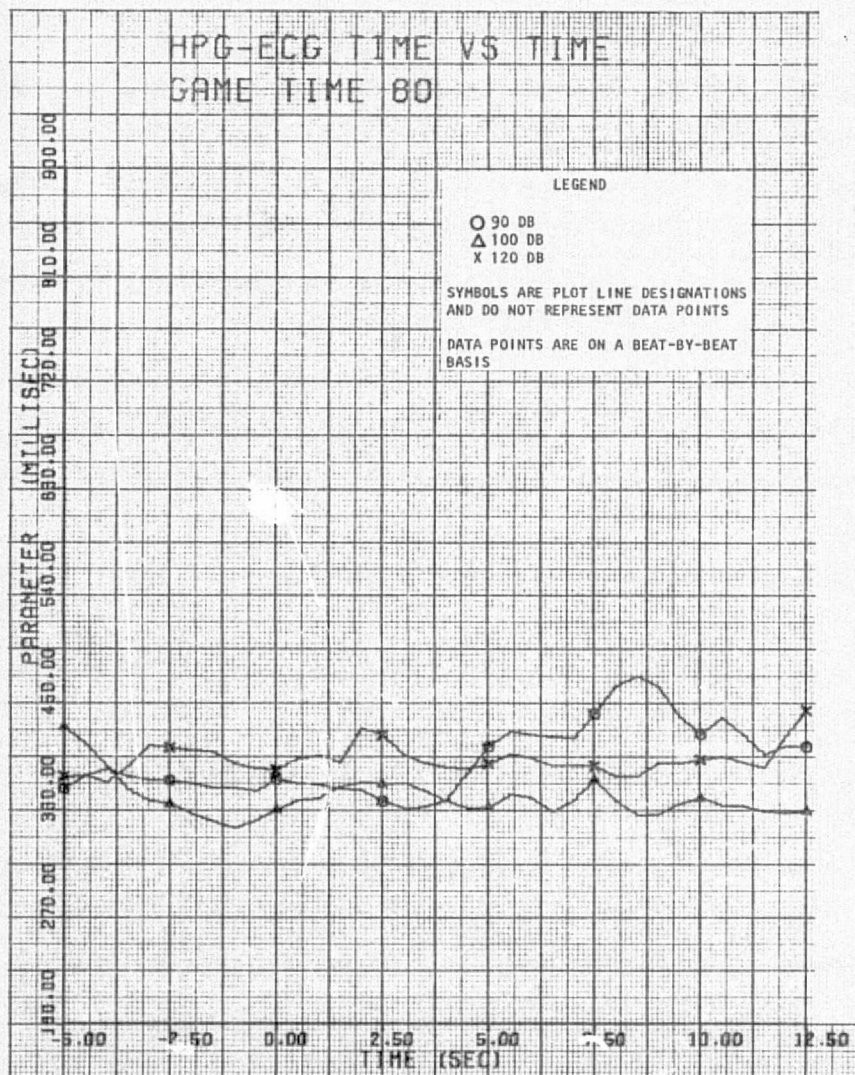
Figure 7-75. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--80-Sec Game Time
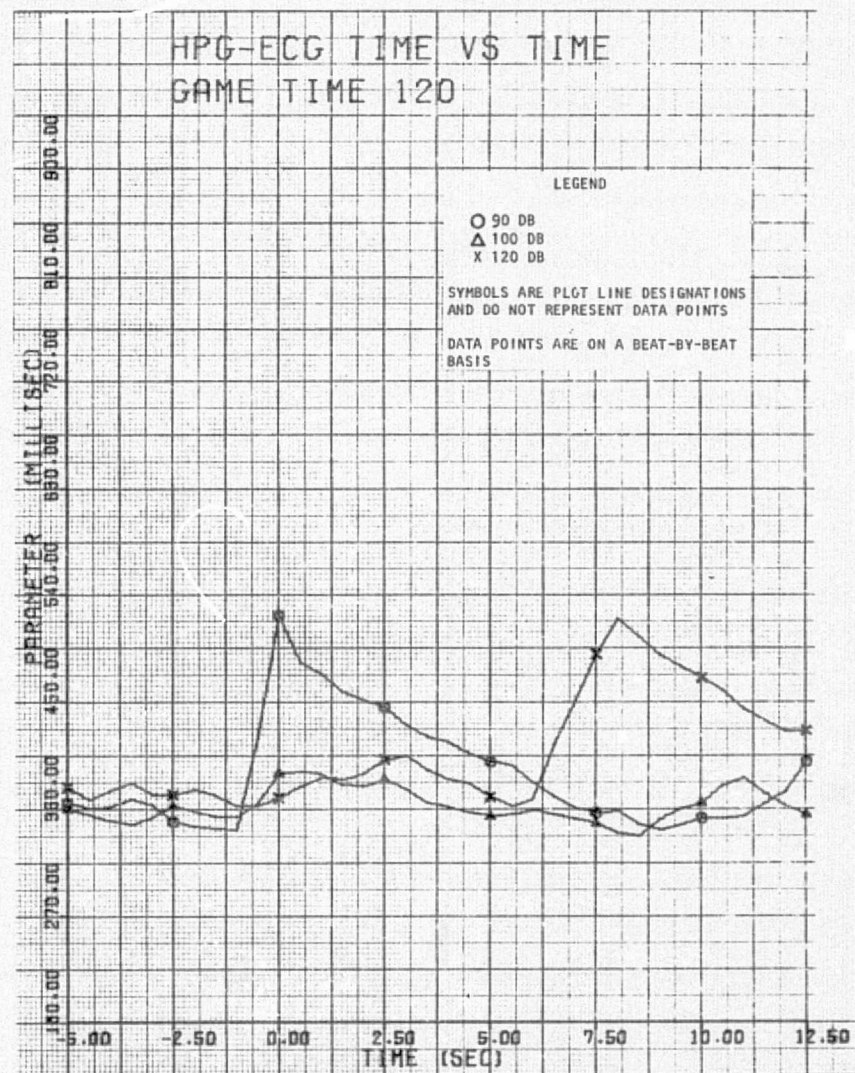


Figure 7-76. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--120-Sec Game Time
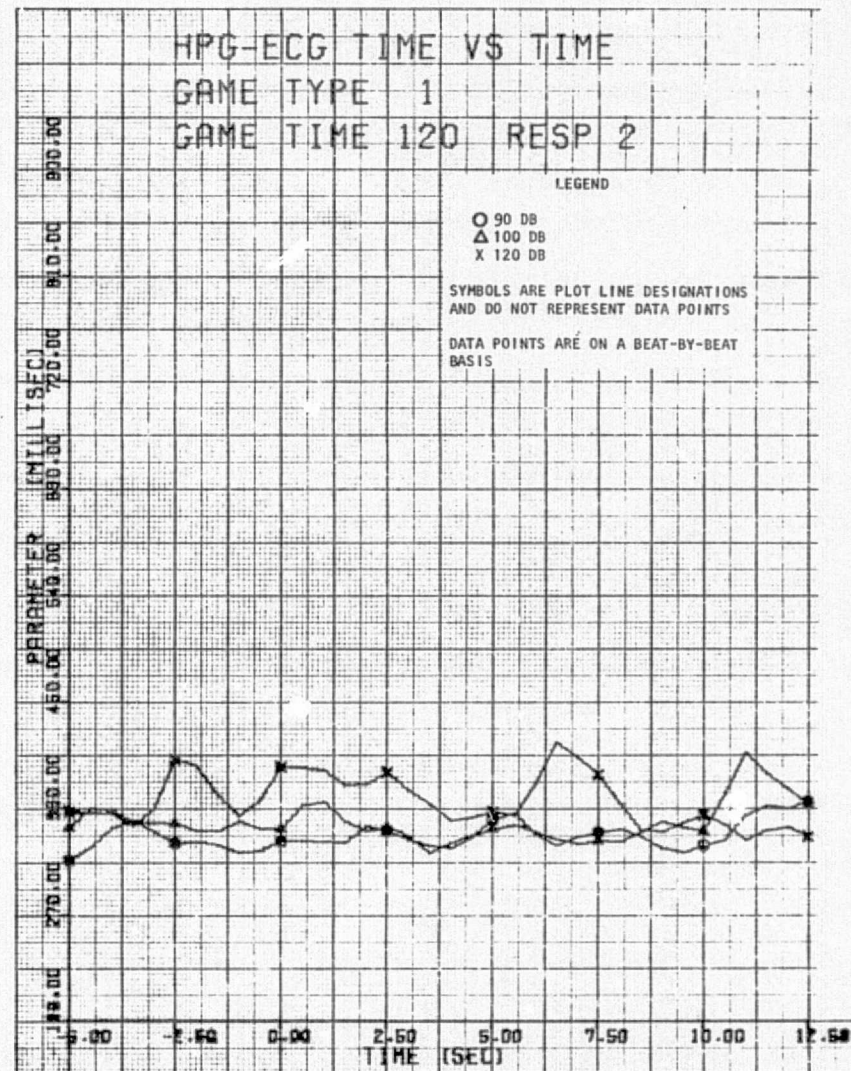
Figure 7-77. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 80-Sec Game Time, Response 1



Figure 7-78. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 120-Sec Game Time, Response 1
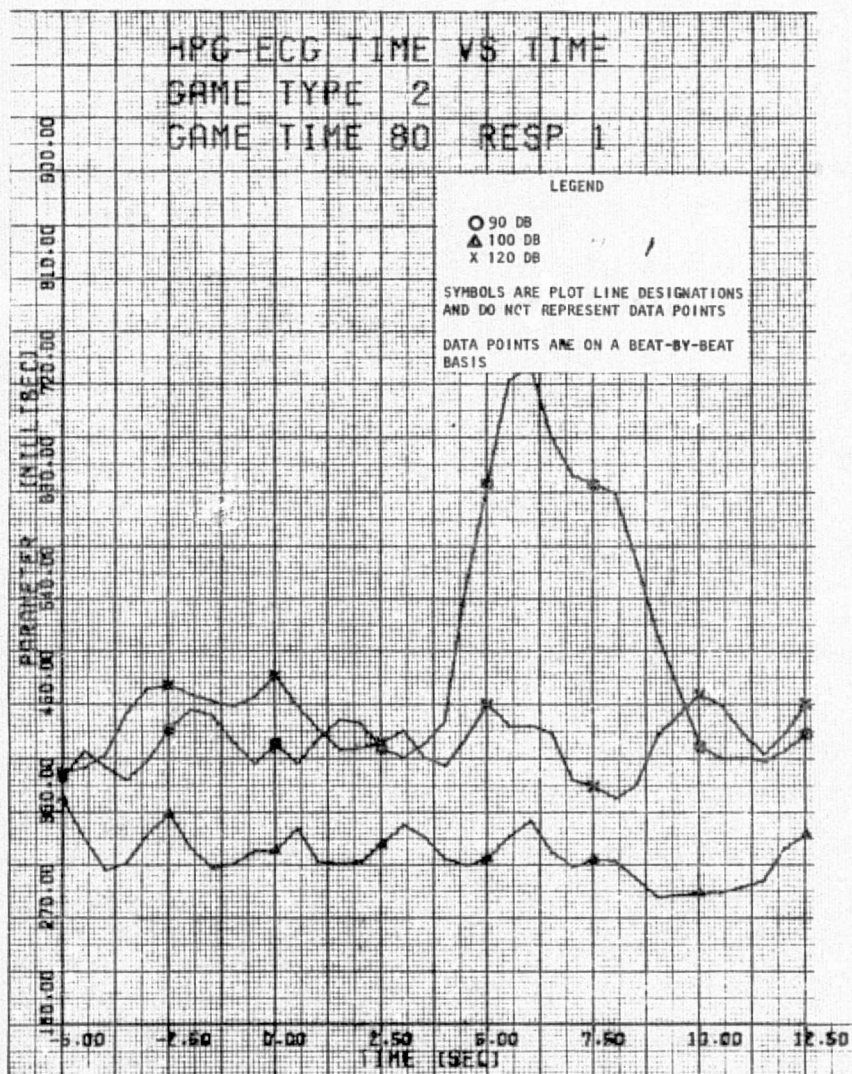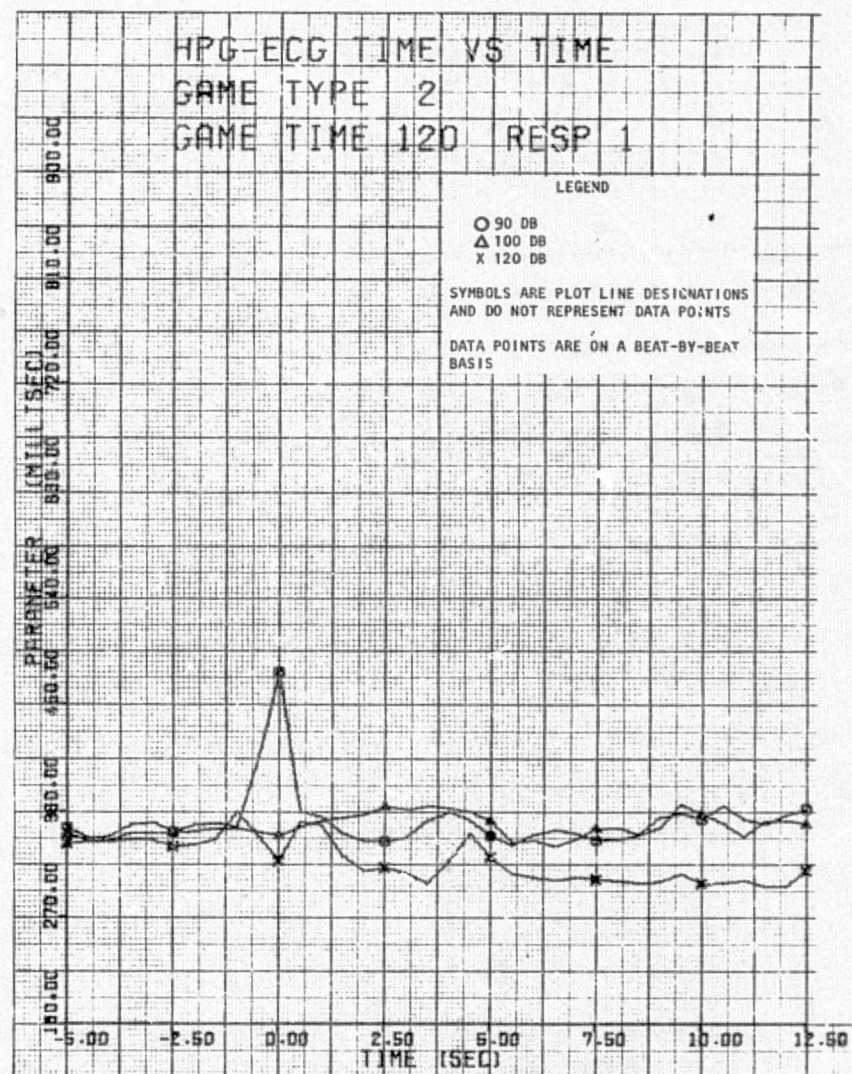
Figure 7-79. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 80-Sec Game Time, Response 2

Figure 7-80. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 120-Sec Game Time, Response 2
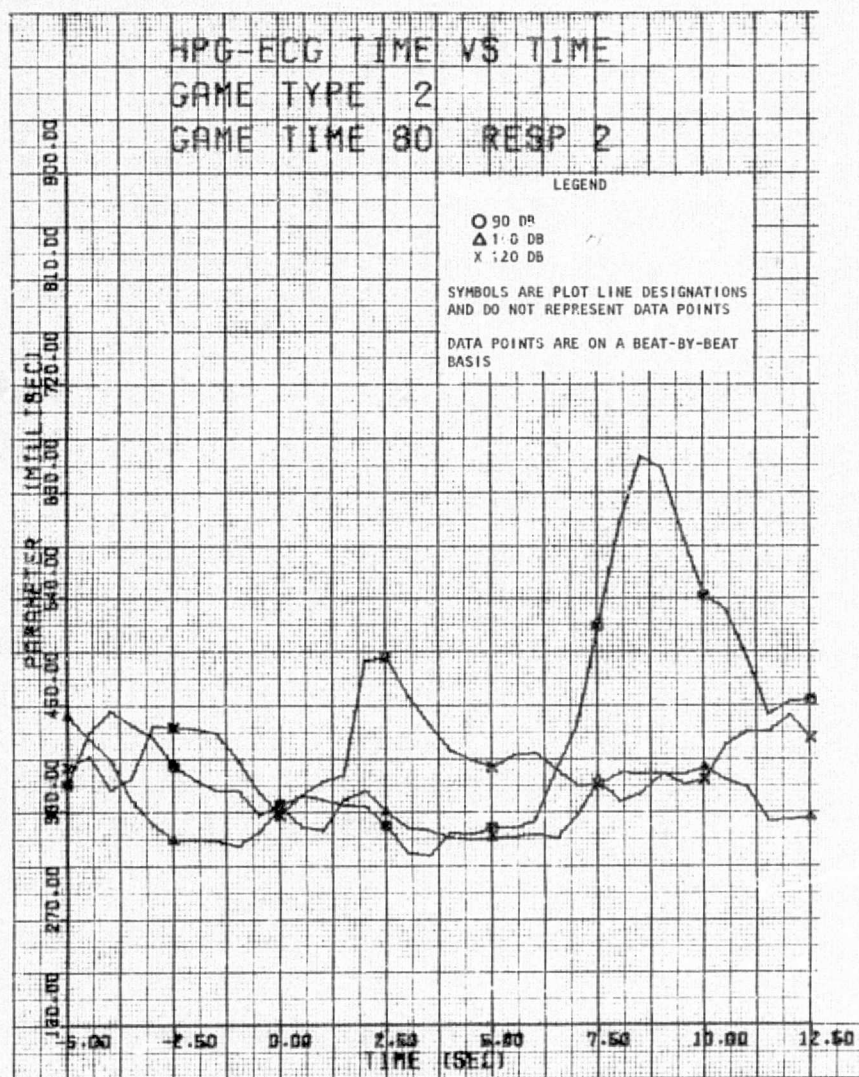
Figure 7-81. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 1



Figure 7-82. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 1

Figure 7-83. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 2
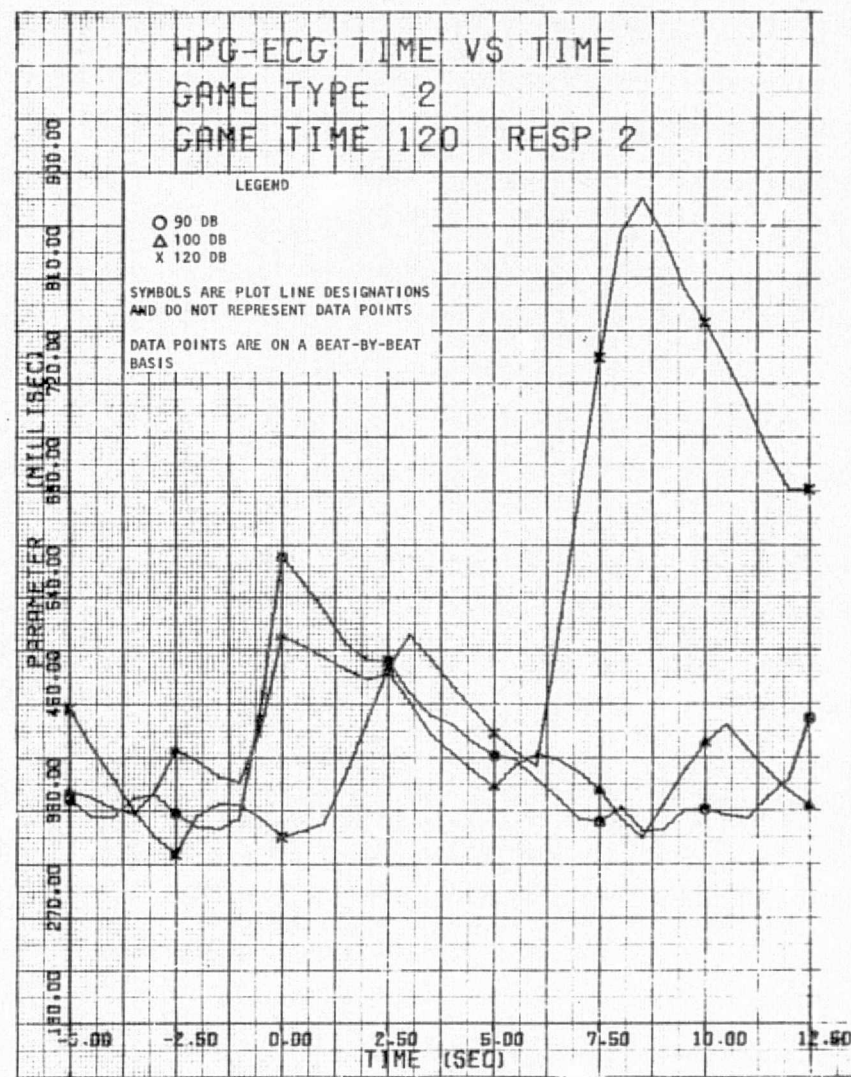
Figure 7-84. Elapsed Time from ECG to HPG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 2
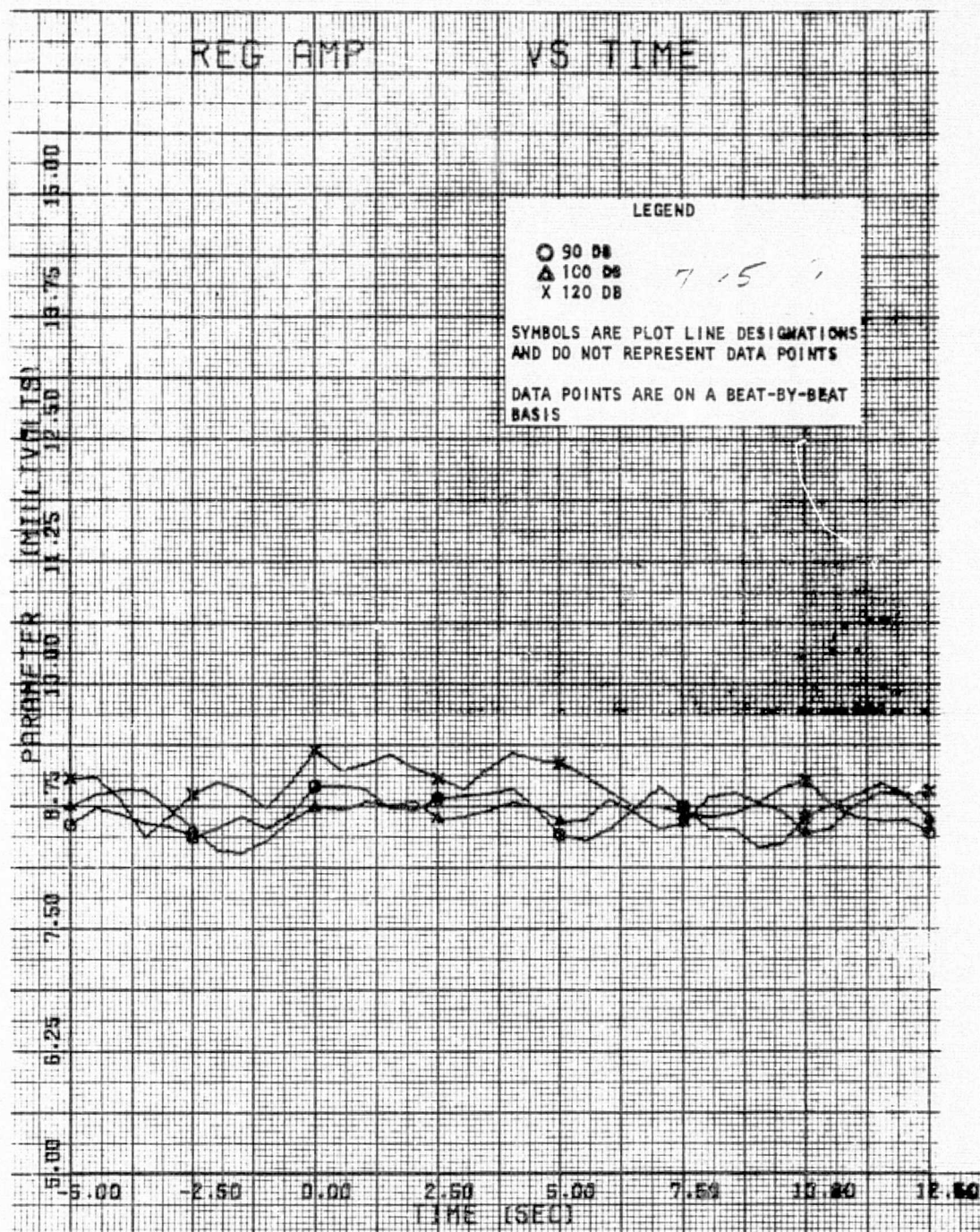
Figure 7-85.  REG Pulse Amplitude for Test Day 3, Conditions
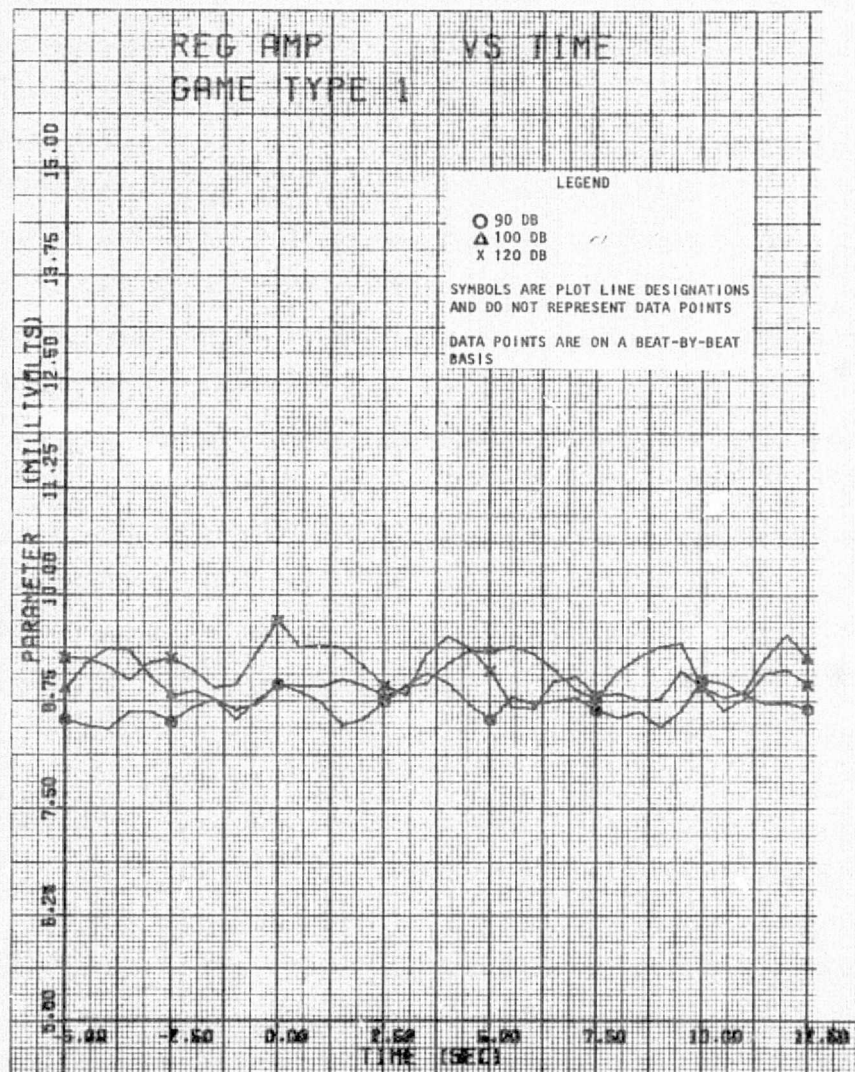5 and 6 (Less 110 db, 100-Sec Task Duration,
VM Task 3)

Figure 7-86.   REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 100 db, 100-Sec Task Duration, VM Task 3)--Game Type 1
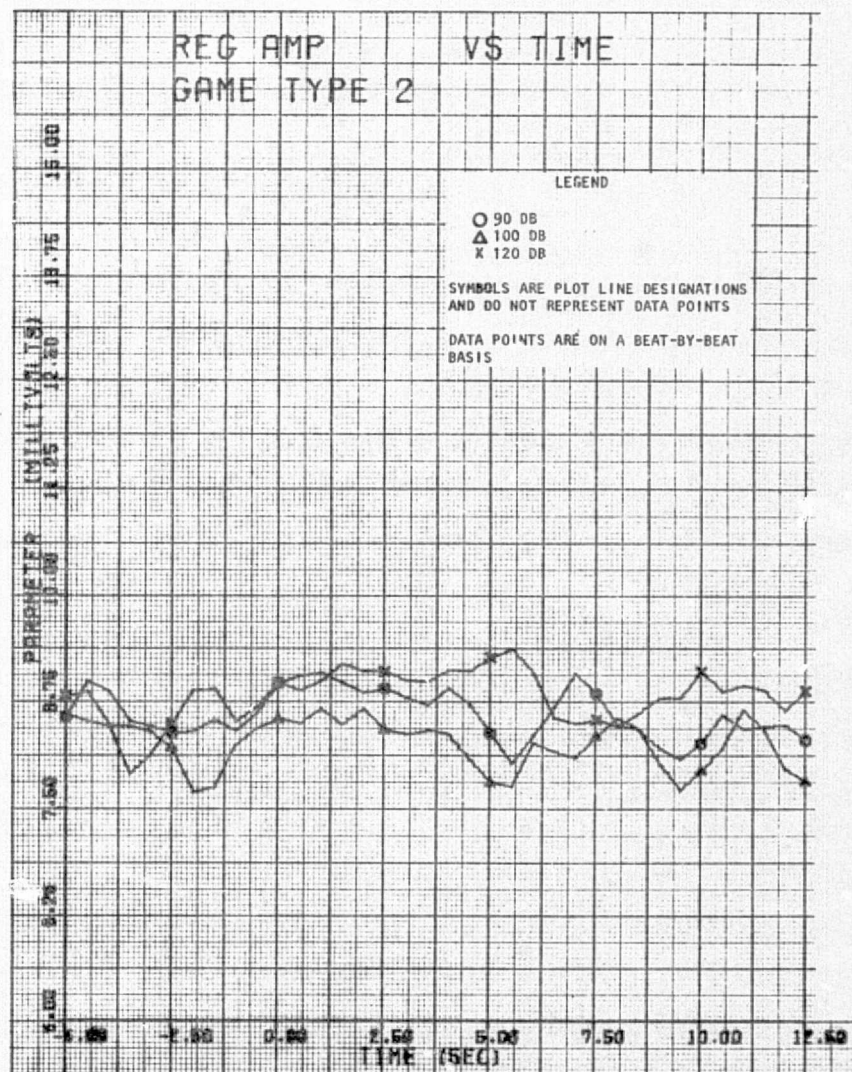
Figure 7-87.   REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100- Sec Task Duration, VM Task 3)--Game Type 2
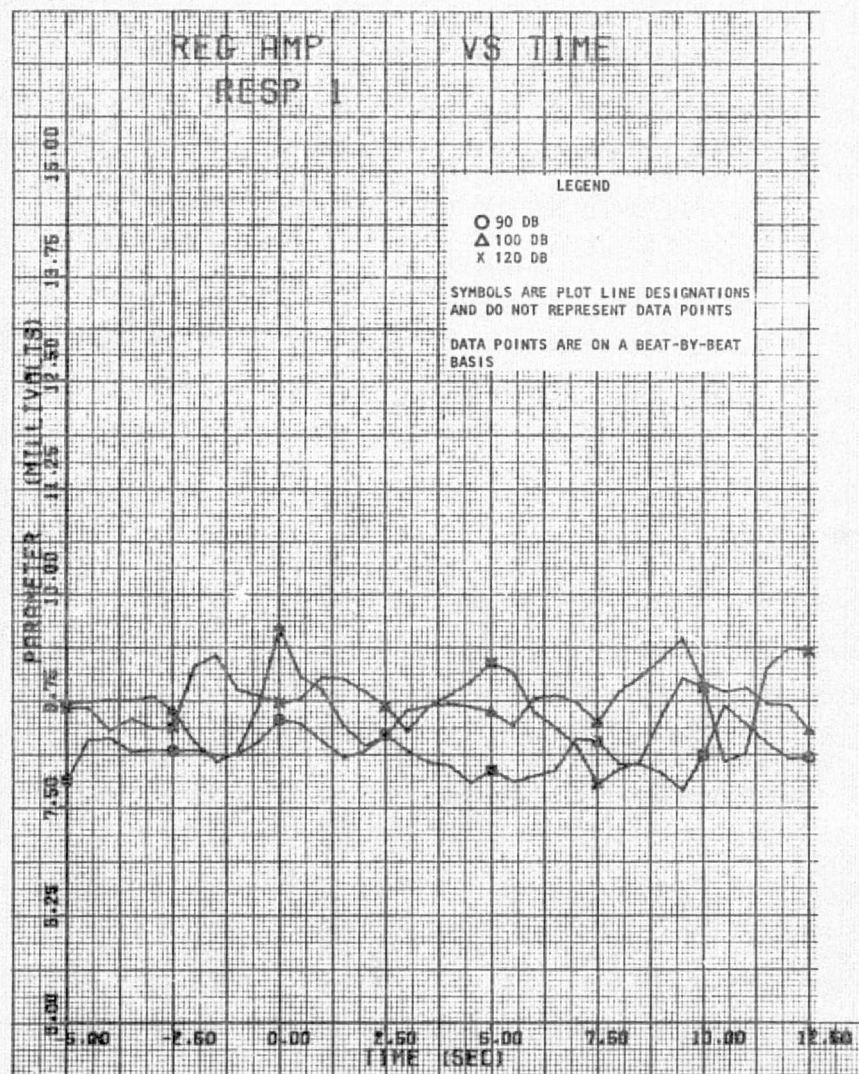
Figure 7-88. REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 1
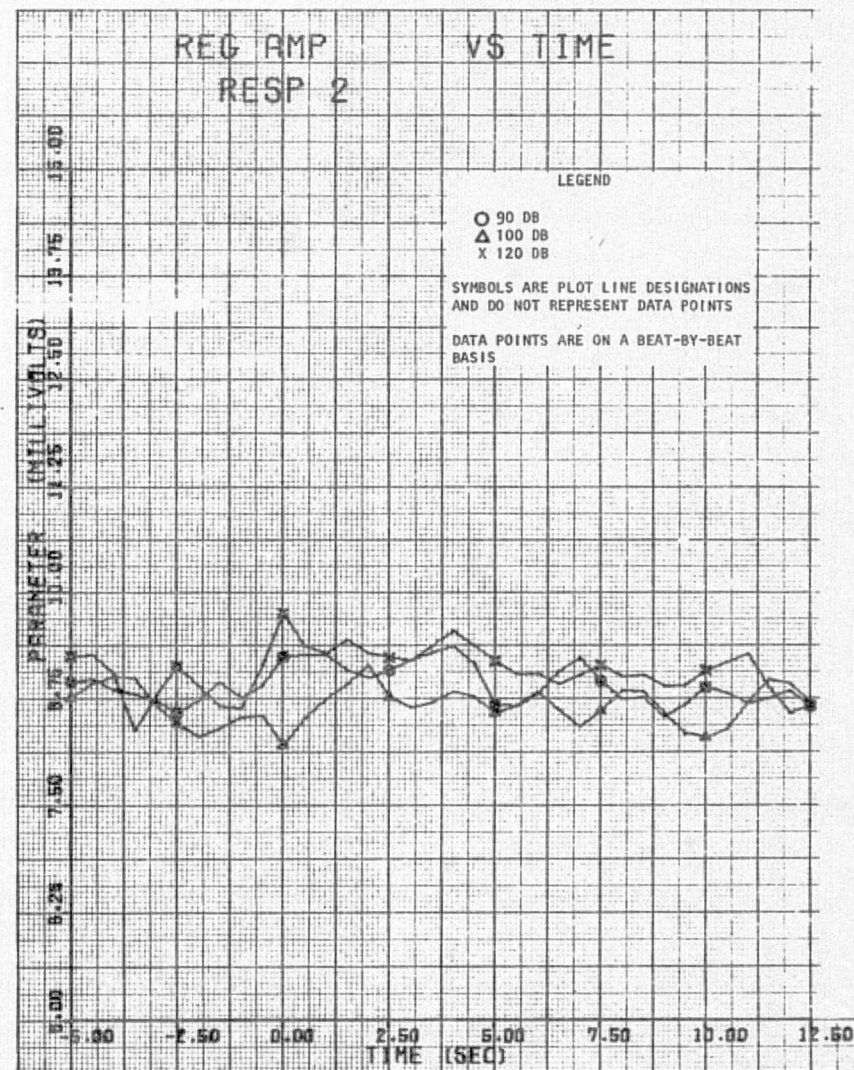
Figure 7-89. REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 2



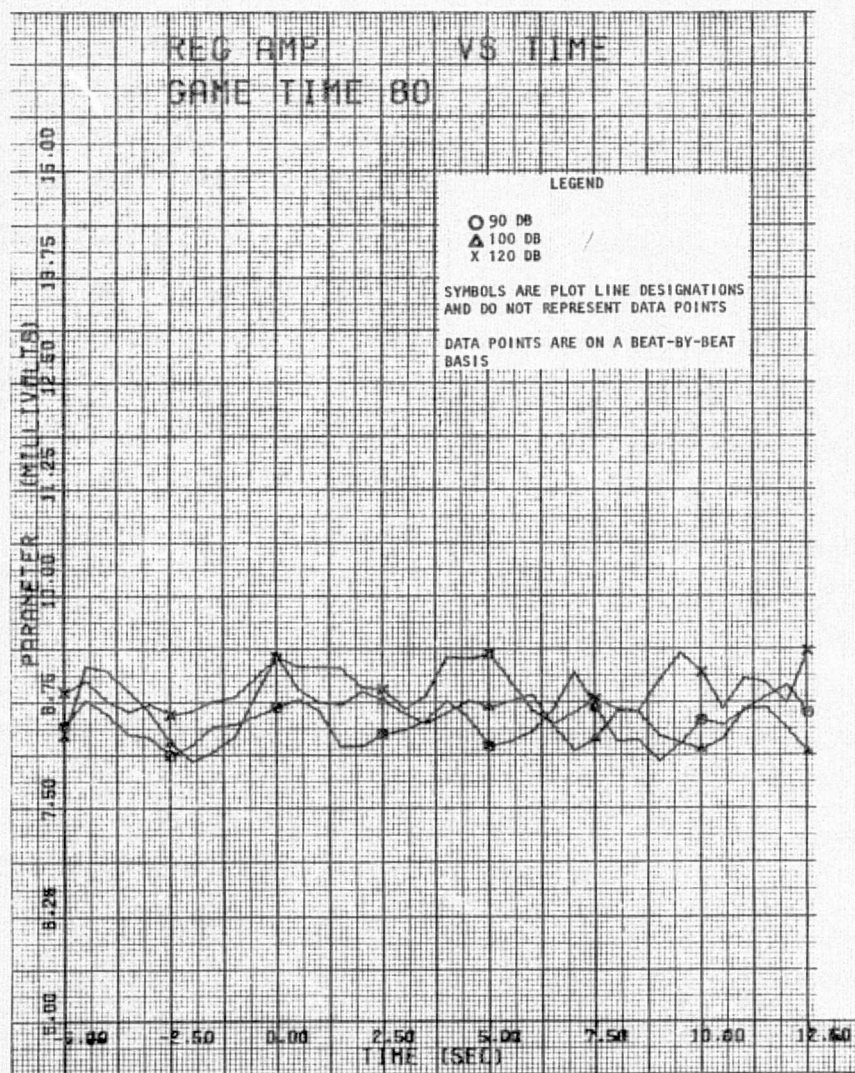7-61

Figure 7-90.   REG Pulse Amplitude for Test Day 3, Conditions
               5 and 6 (Less 110 db, 100-Sec Task Duration,
               VM Task 3)--80-Sec Game Time

Figure 7-91.   REG Pulse Amplitude for Test Day 3, Conditions
               5 and 6 (Less 110 db, 100-Sec Task Duration,
               VM Task 3)--120-Sec Game Time

Figure 7-92.  REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)—Game Type 1, 80-Sec Game Time, Response 1

Figure 7-93.  REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)—Game Type 1, 120-Sec Game Time, Response 1

Figure 7-94. REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 80-Sec Game Time, Response 2



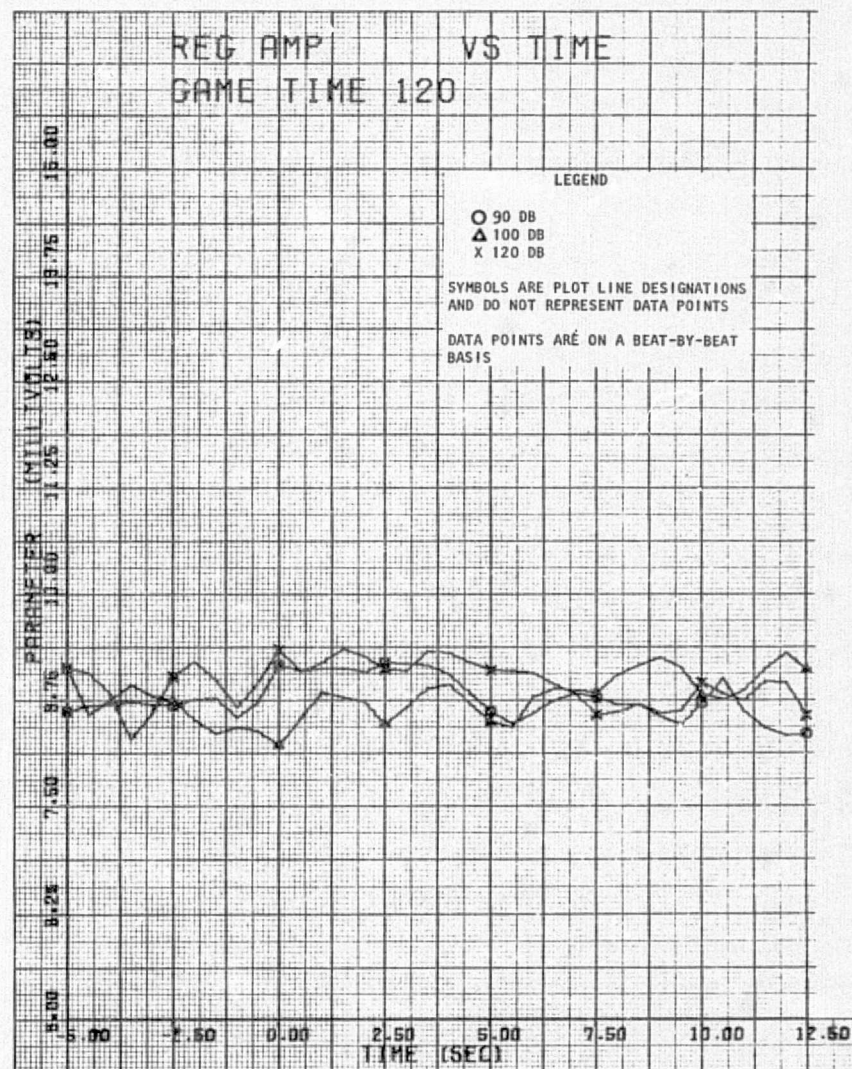Figure 7-95. REG Pulse Amplitude for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 120-Sec Game Time, Response 2
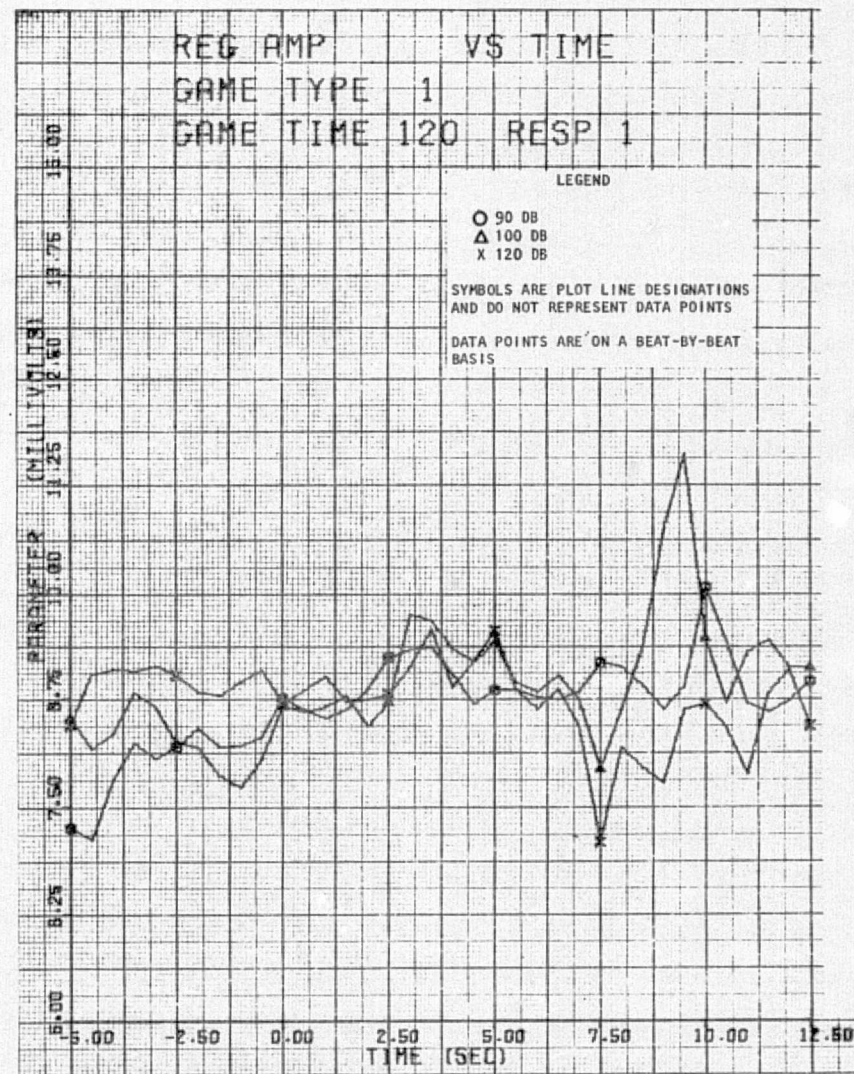
Figure 7-96.   REG Pulse Amplitude for Test Day 3, Conditions
5 and 6 (Less 110 db, 100-Sec Task Duration,
VM Task 3)--Game Type 2, 80-Sec Game Time,
Response 1

Figure 7-97.   REG Pulse Amplitude for Test Day 3, Conditions
5 and 6 (Less 110 db, 100-Sec Task Duration,
VM Task 3)--Game Type 2, 120-Sec Game Time,
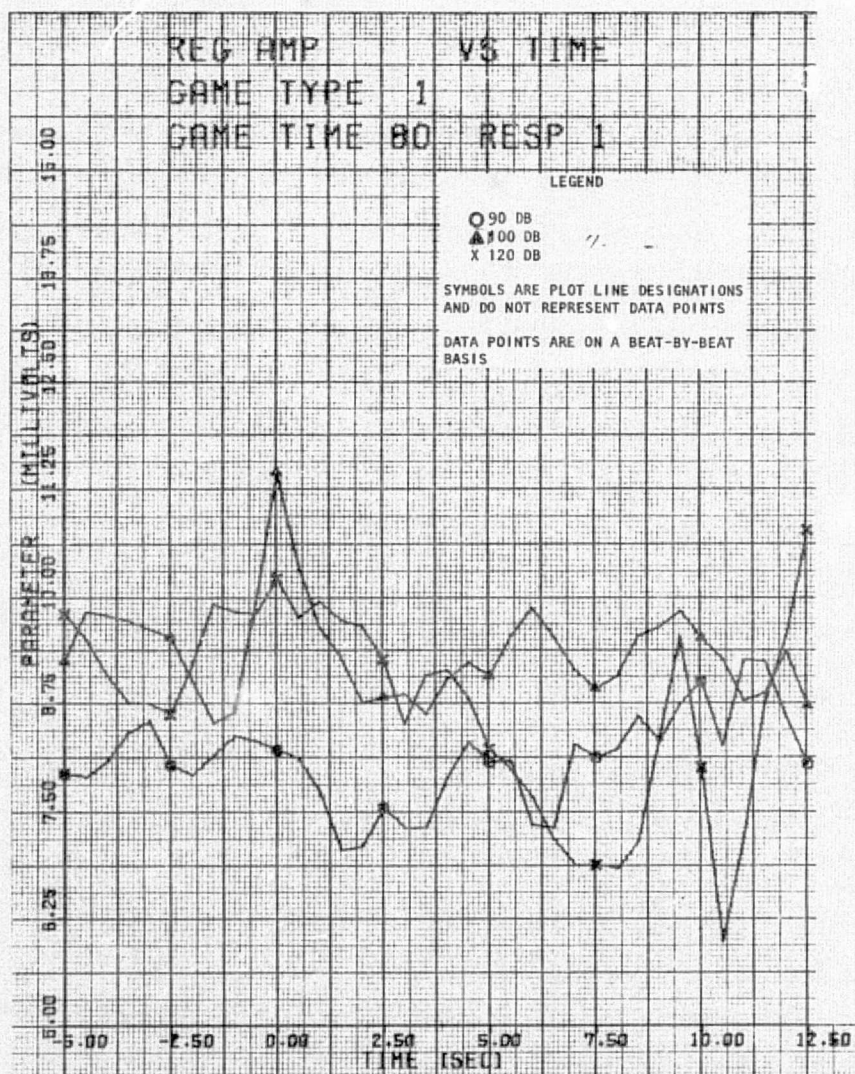Response 1

Figure 7-98.   REG Pulse Amplitude for Test Day 3, Conditions
5 and 6 (Less 110 db, 100-Sec Task Duration,
VM Task 3)--Game Type 2, 80-Sec Game Time,
Response 2

Figure 7-99.   REG Pulse Amplitude for Test Day 3, Conditions
5 and 6 (Less 110 db, 100-Sec Task Duration,
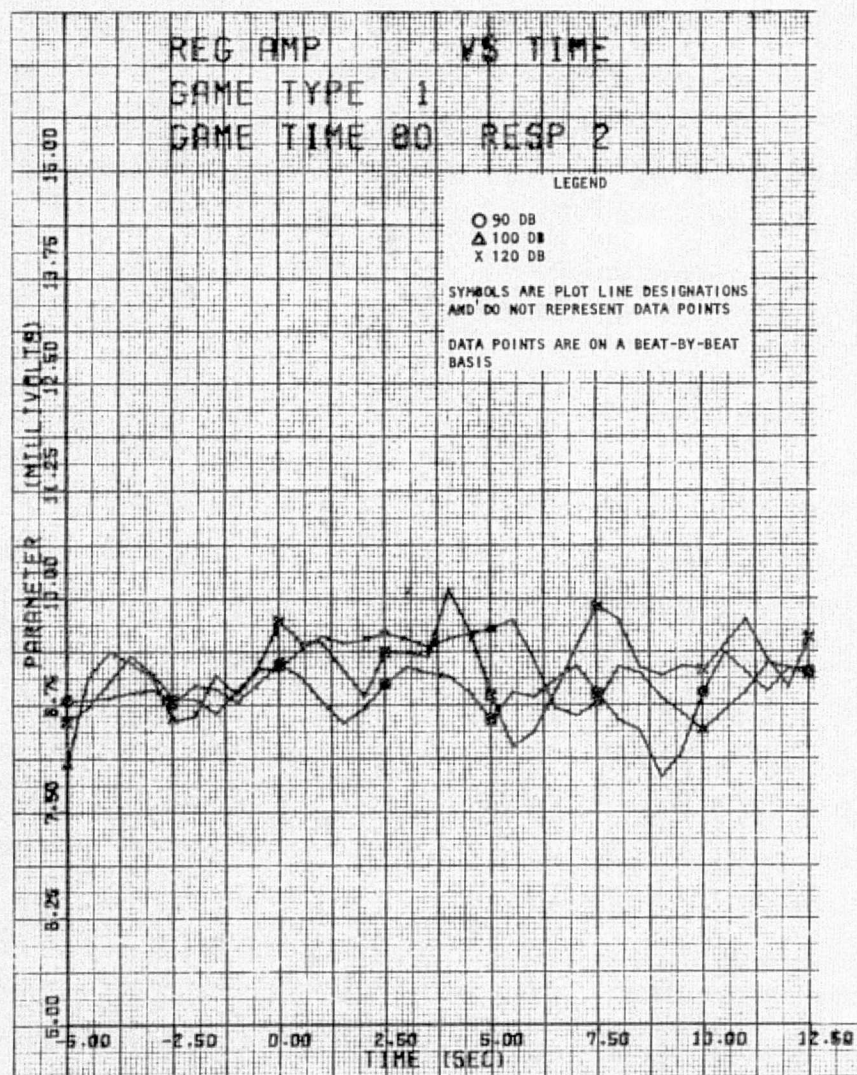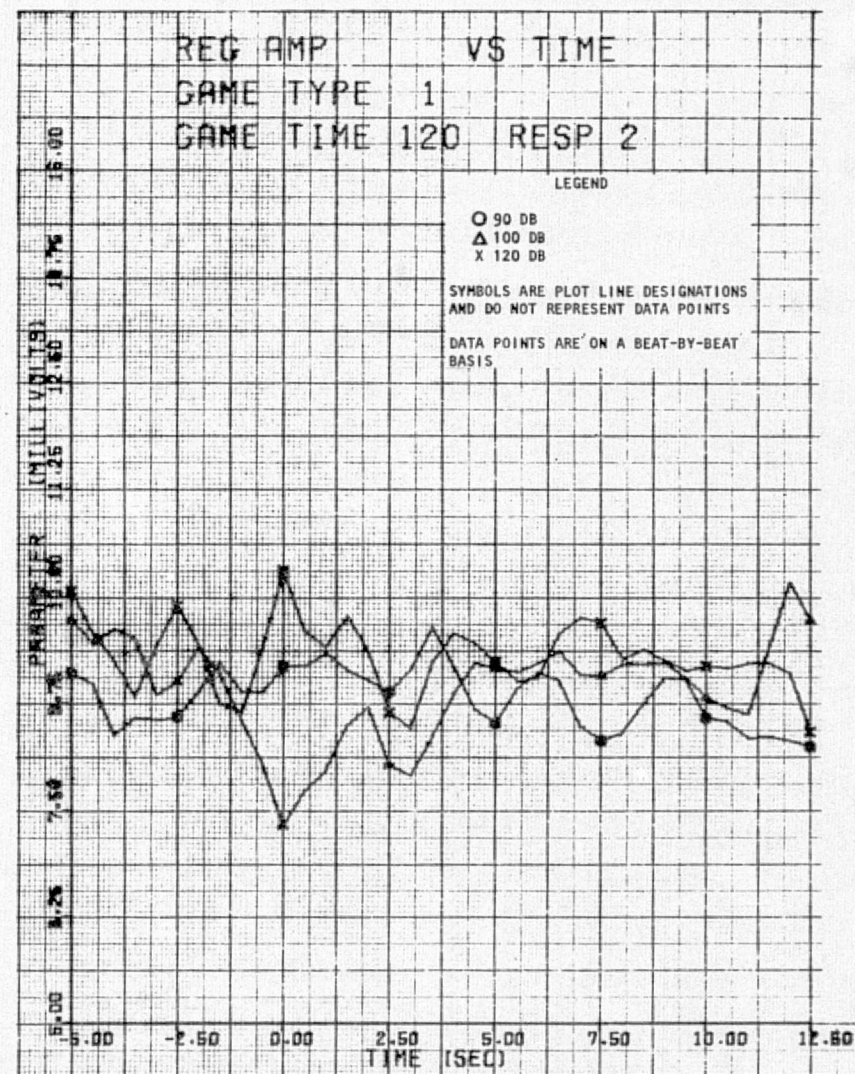VM Task 3)--Game Type 2, 120-Sec Game Time,
Response 2

Figure 7-100. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)

Figure 7-101. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1



Figure 7-102. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2

**Figure 7-103.** Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 1



**Figure 7-104.** Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 2

**Figure 7-105.** Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--80-Sec Game Time



**Figure 7-106.** Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--120-Sec Game Time

Figure 7-107. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)—Game Type 1, 80-Sec Game Time, Response 1
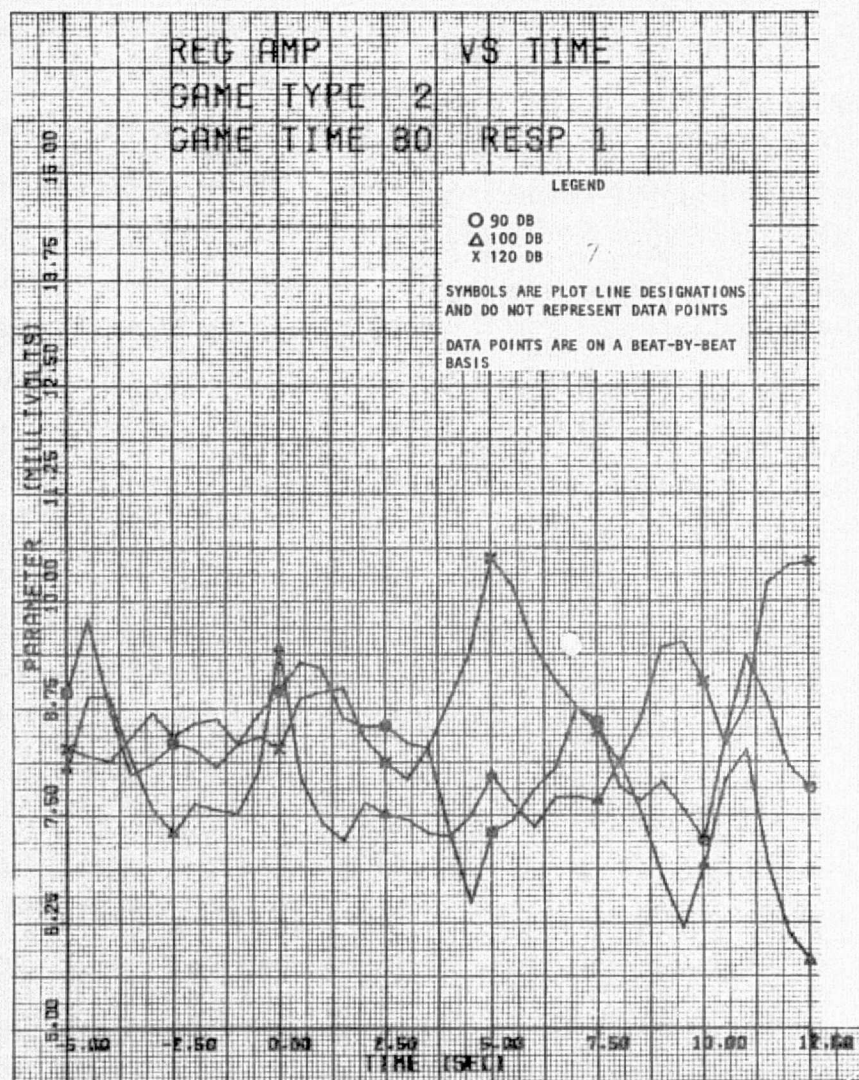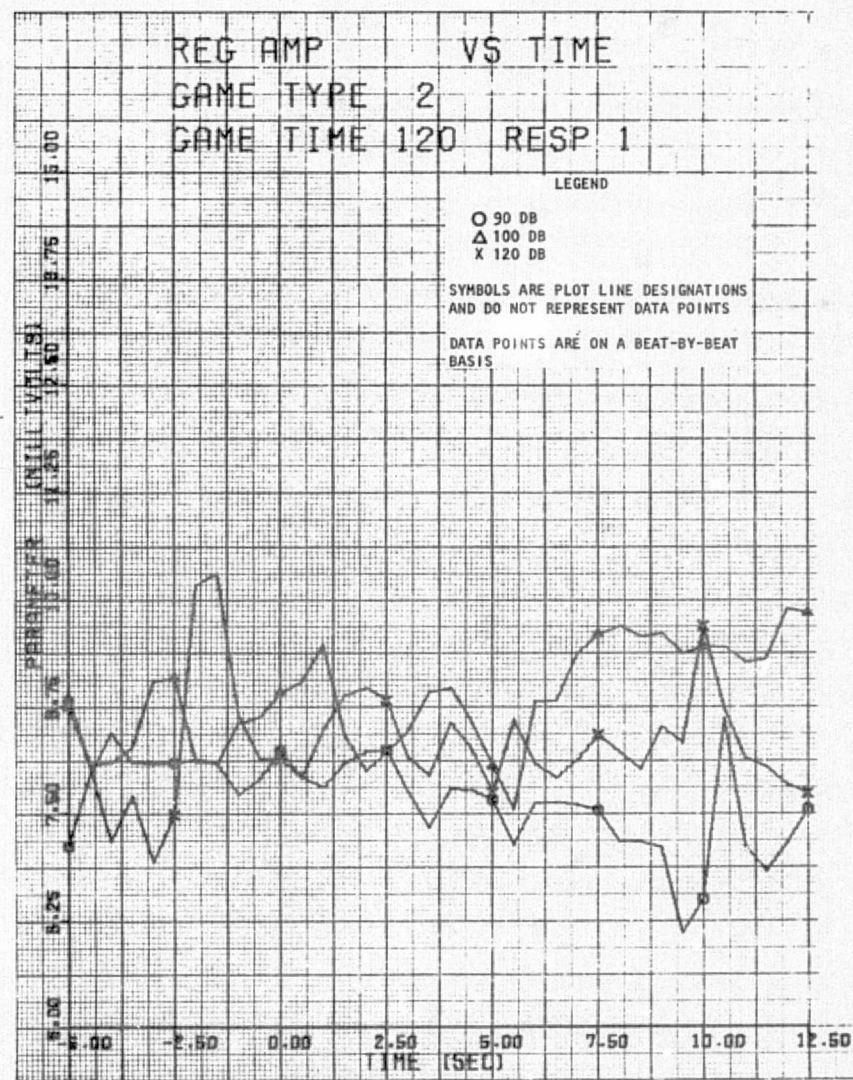


Figure 7-108. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)—Game Type 1, 120-Sec Game Time, Response 1

**Figure 7-109.** Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 80-Sec Game Time, Response 2

**Figure 7-110.** Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 120-Sec Game Time, Response 2

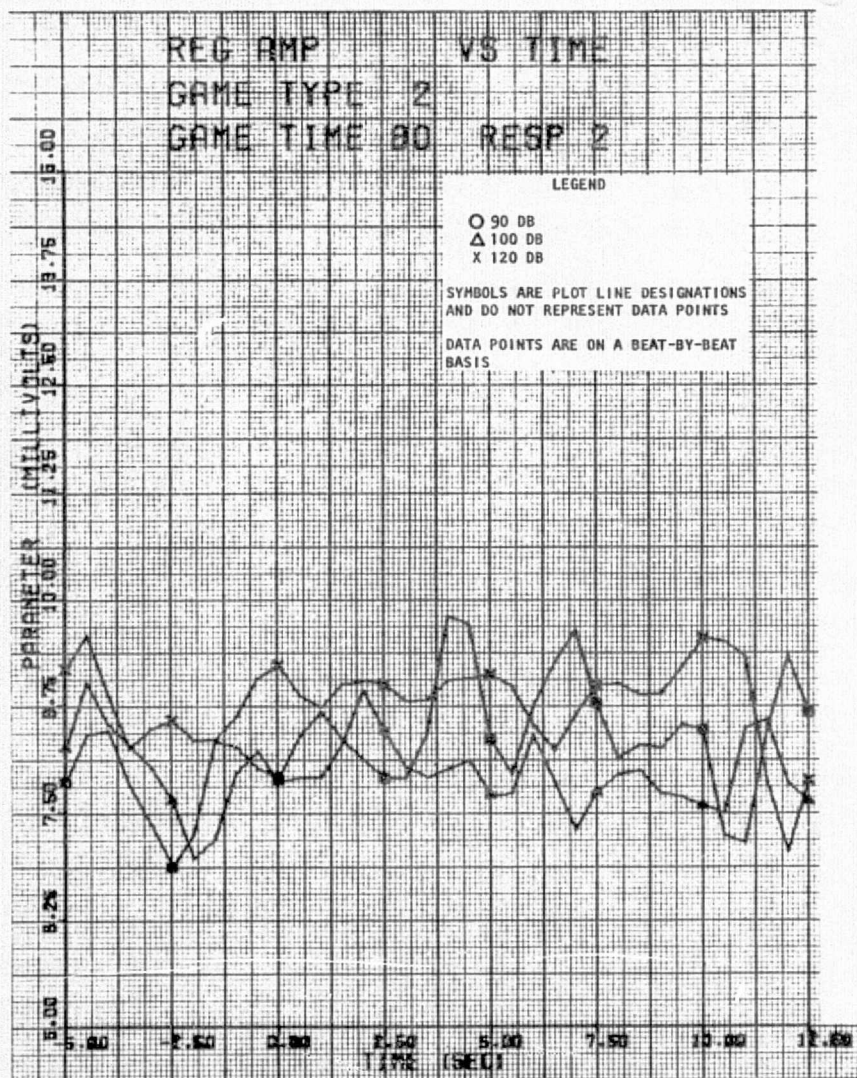Figure 7-111. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 1

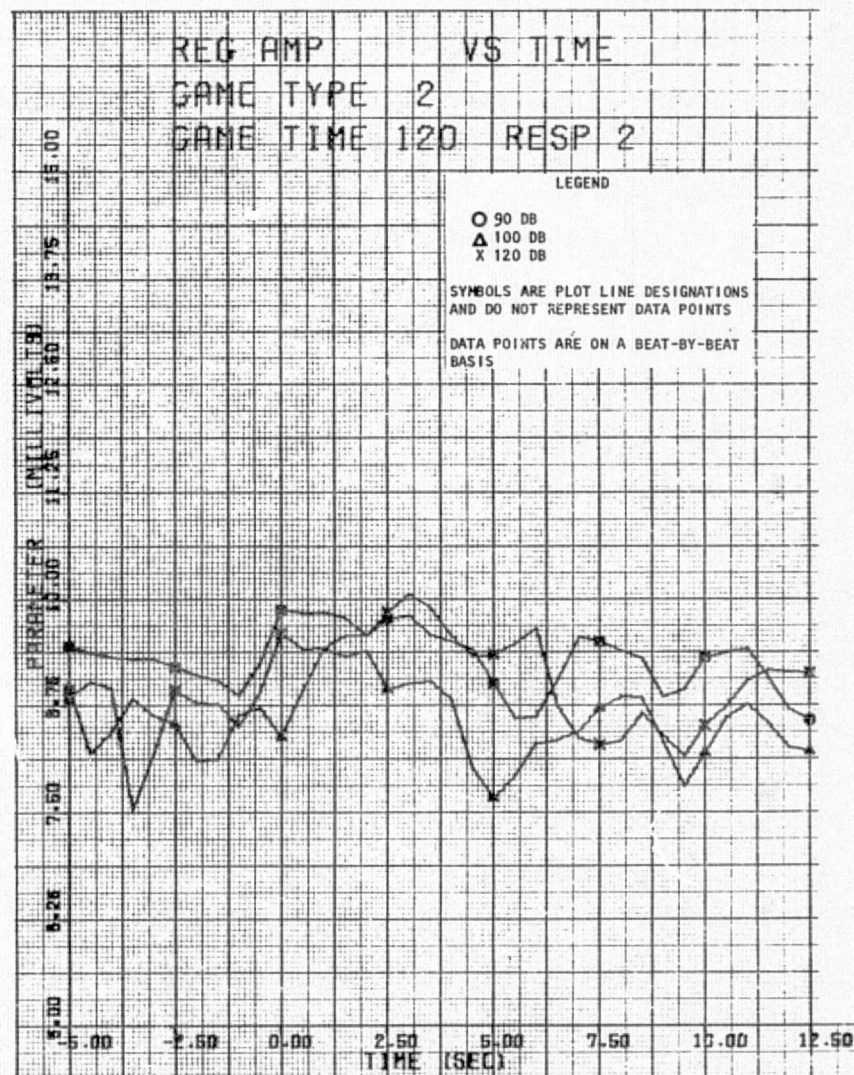Figure 7-112. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 1

Figure 7-113. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 2

Figure 7-114. Elapsed Time from ECG to REG for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 2
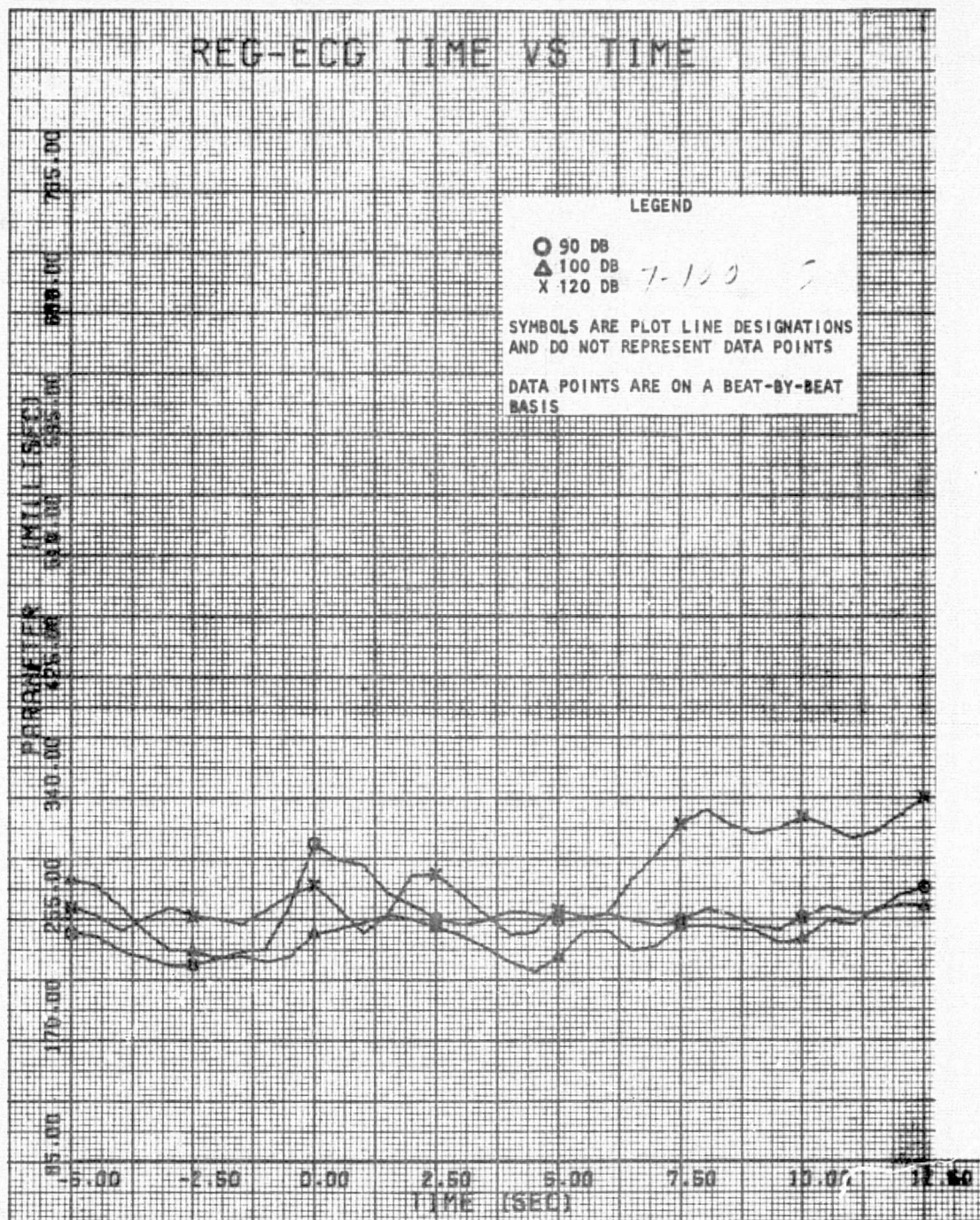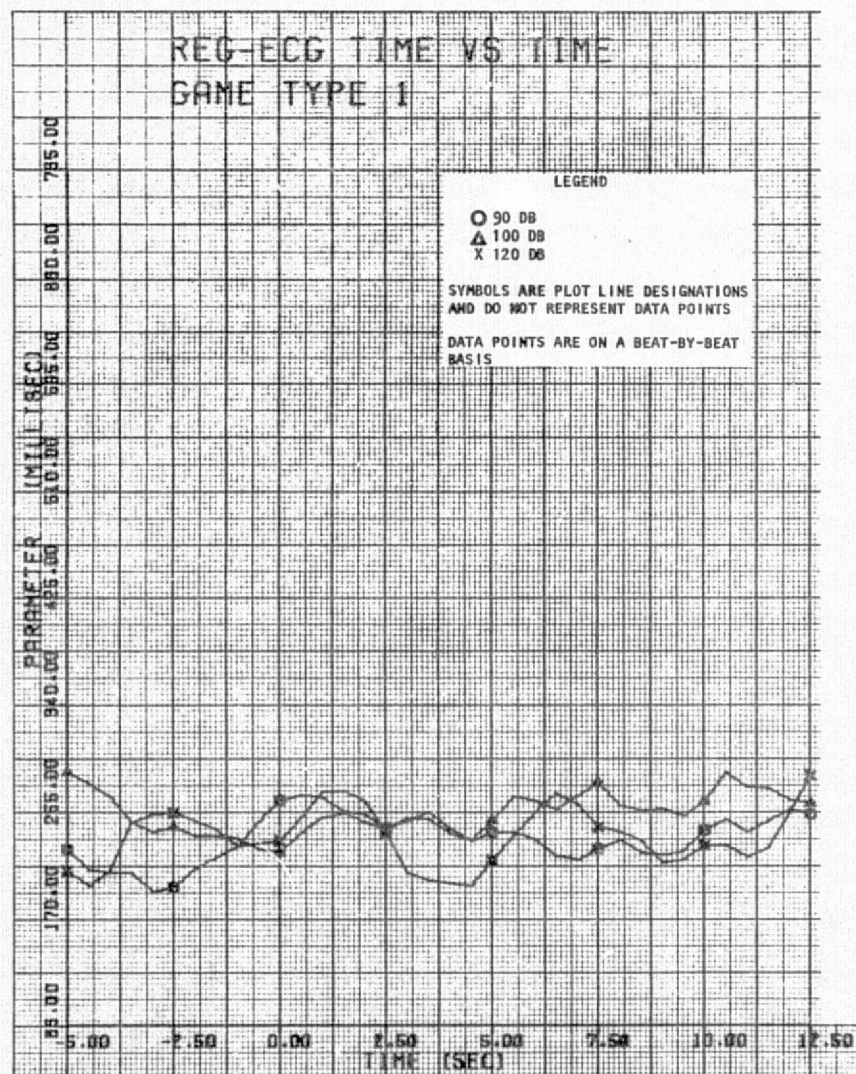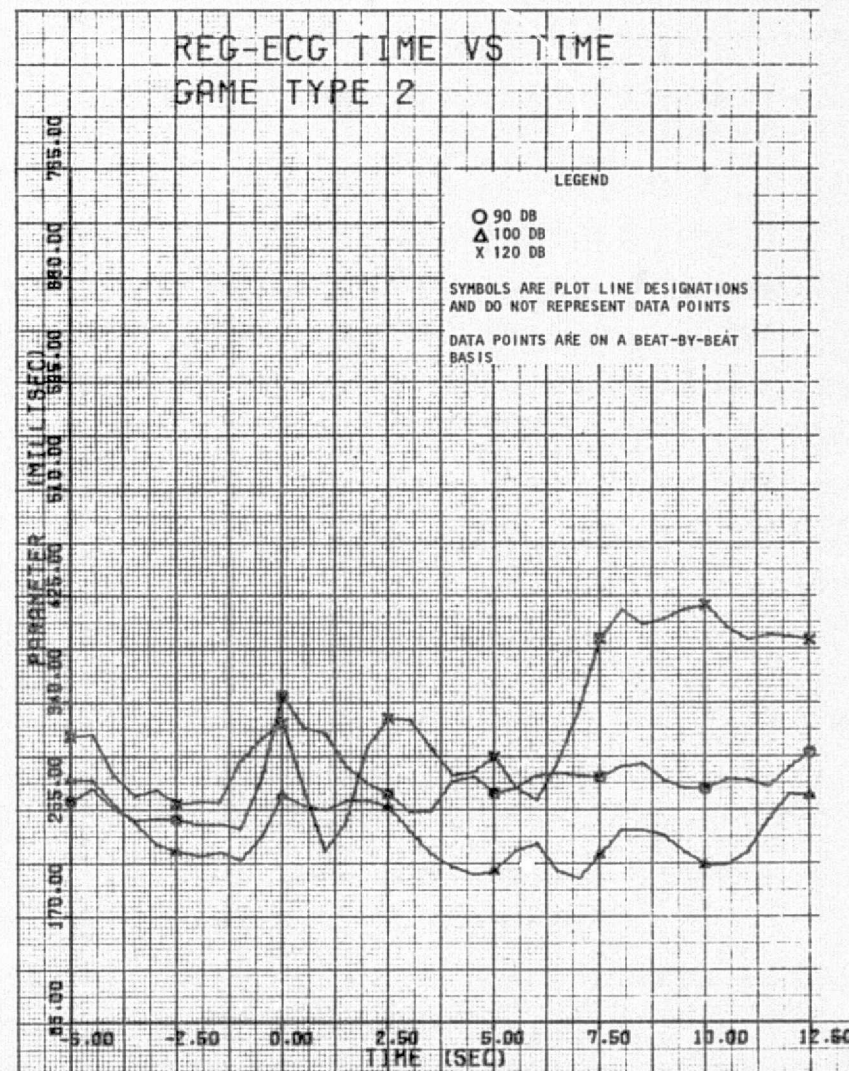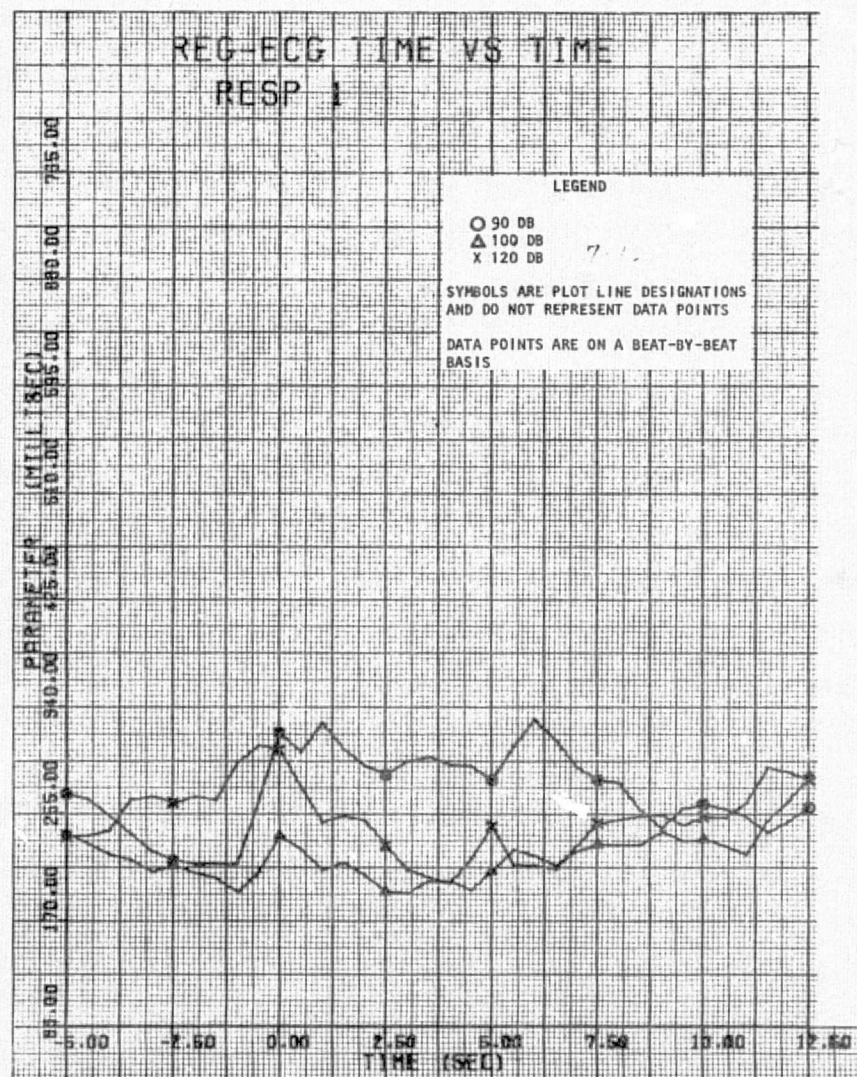
Figure 7-115. REG-FPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)

Figure 7-116.  REG-FPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1



Figure 7-117.  REG-FPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 2

Figure 7-118.  REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 1



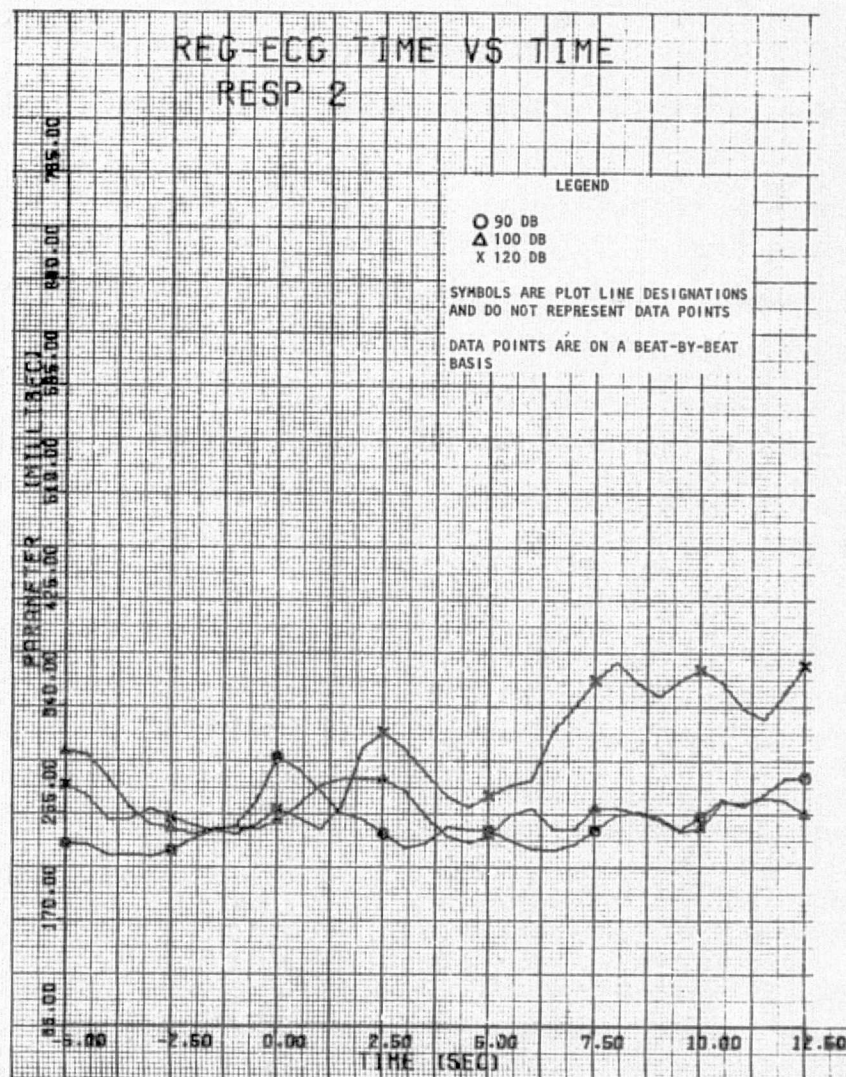Figure 7-119.  REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 2
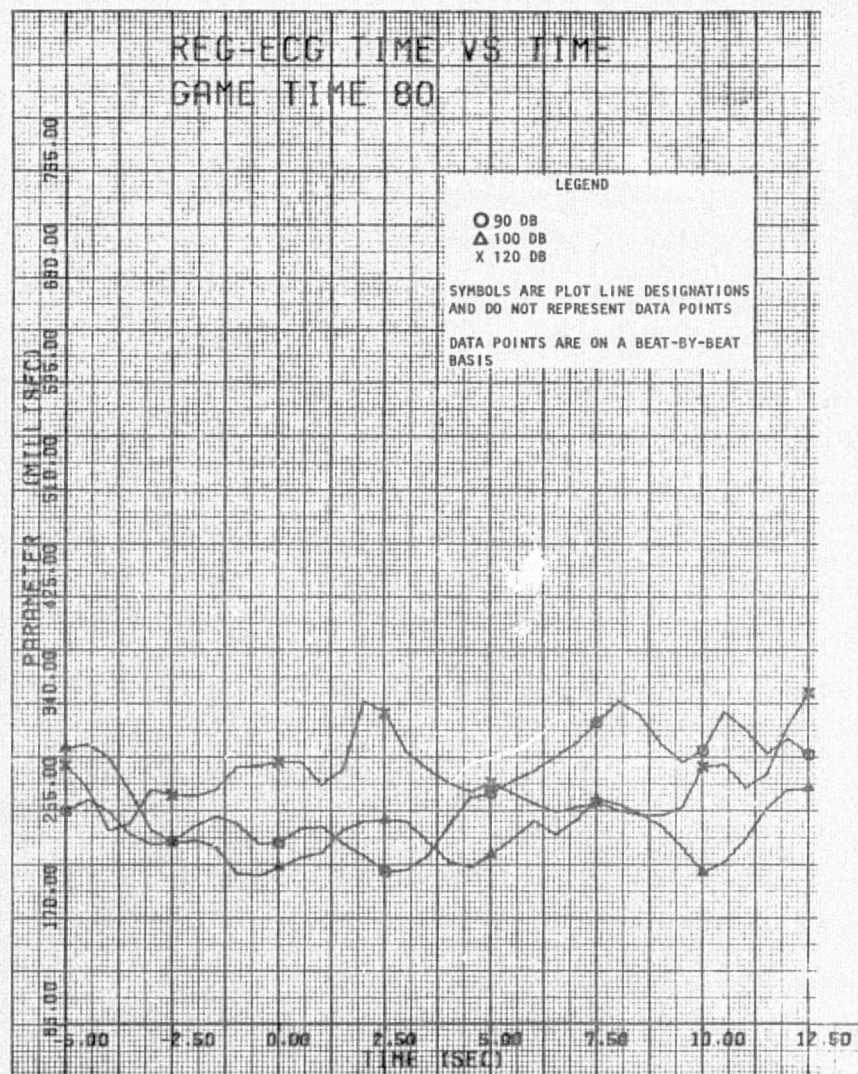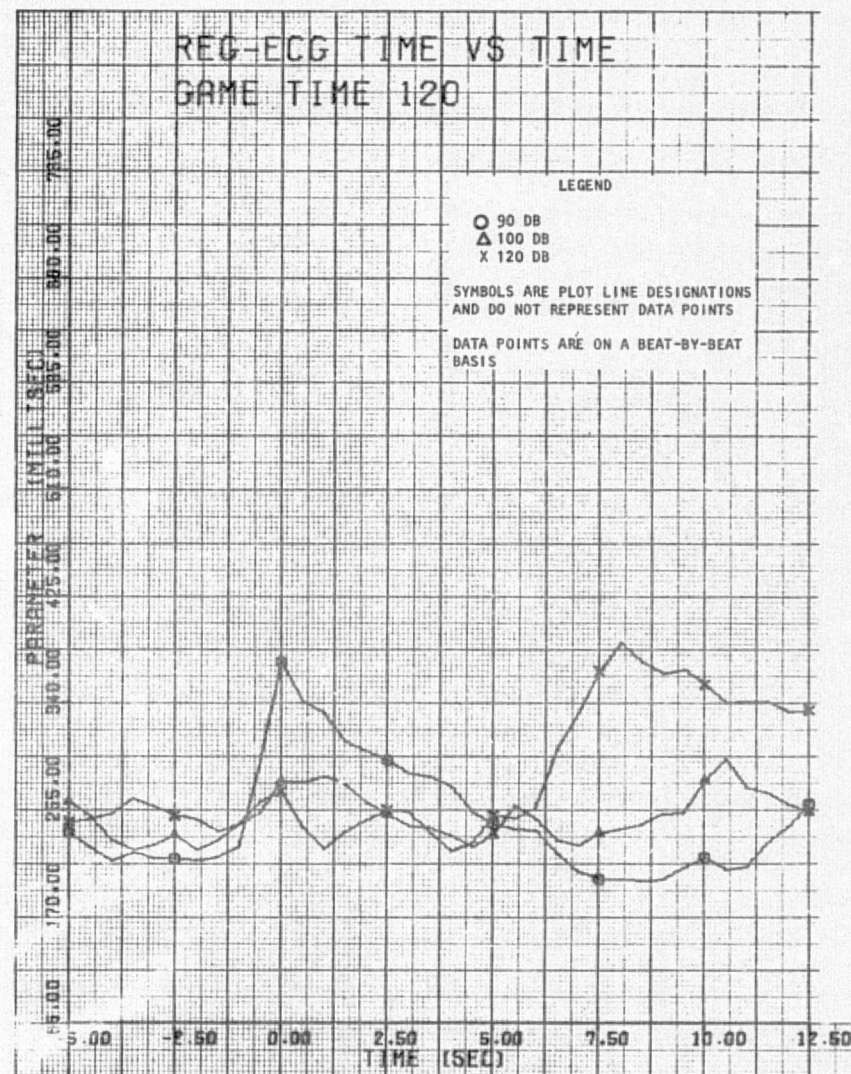
Figure 7-120. REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--80-Sec Game Time

Figure 7-121. REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--120-Sec Game Time

Figure 7-122.　REG-FPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1,
80-Sec Game Time, Response 1

Figure 7-123.　REG-FPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1,
120-Sec Game Time, Response 1
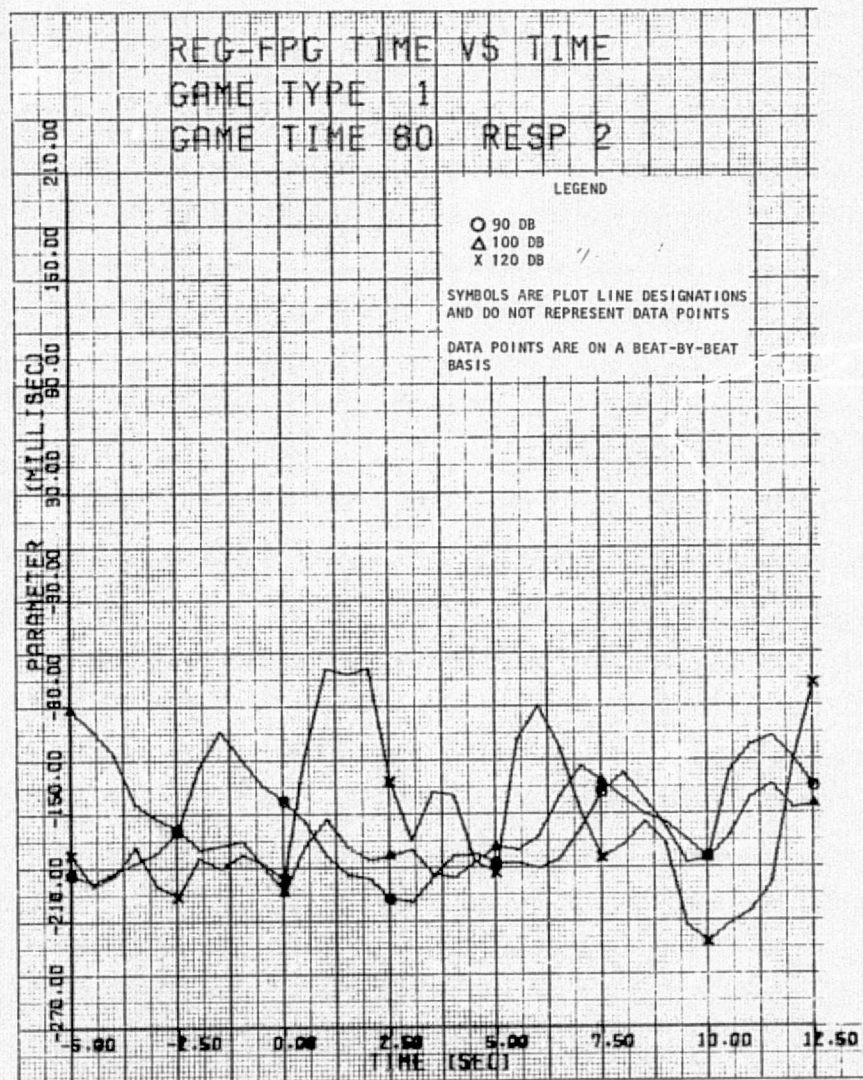
Figure 7-124.  REG-FPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1,
80-Sec Game Time, Response 2
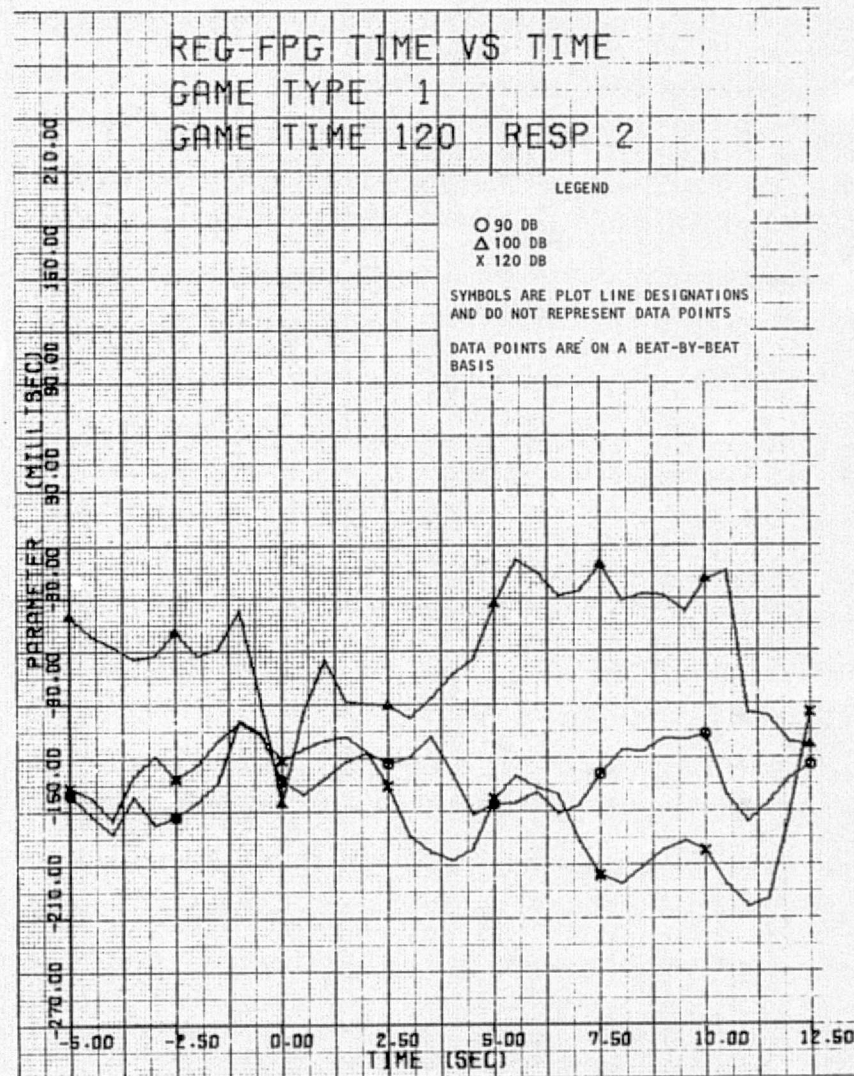
Figure 7-125.  REG-FPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
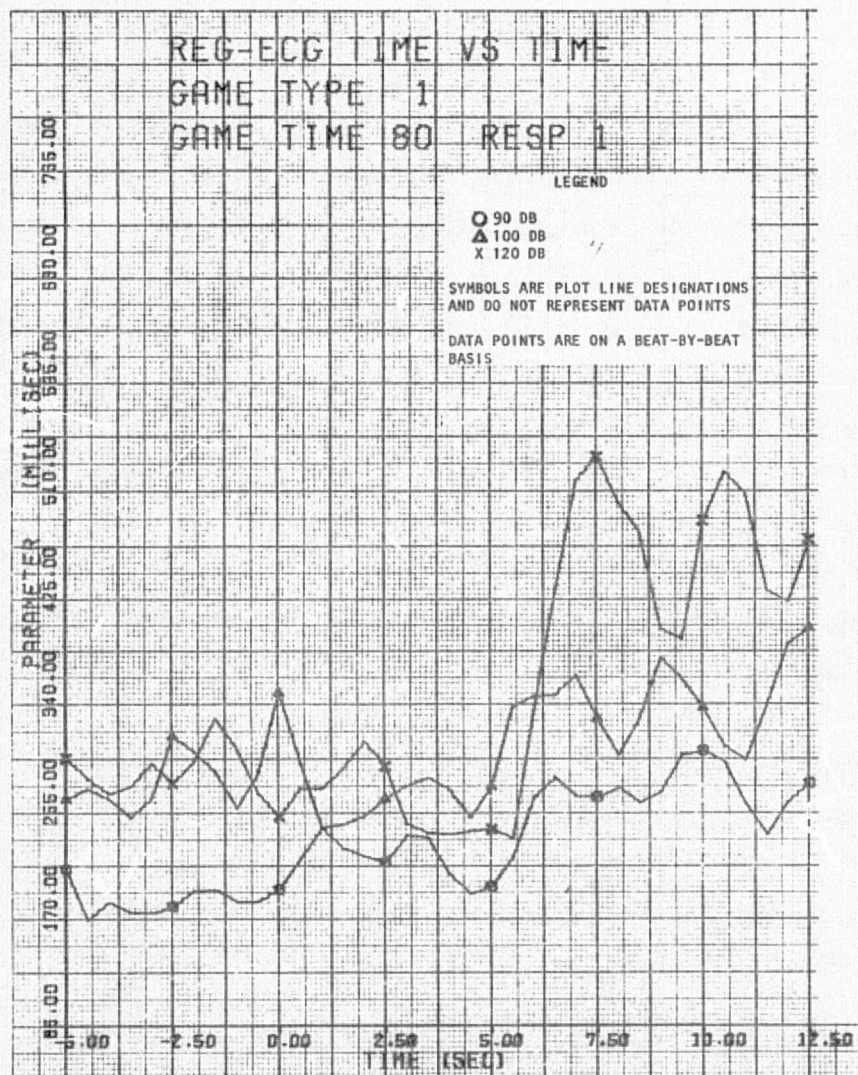Task Duration, VM Task 3)--Game Type 1,
120-Sec Game Time, Response 2
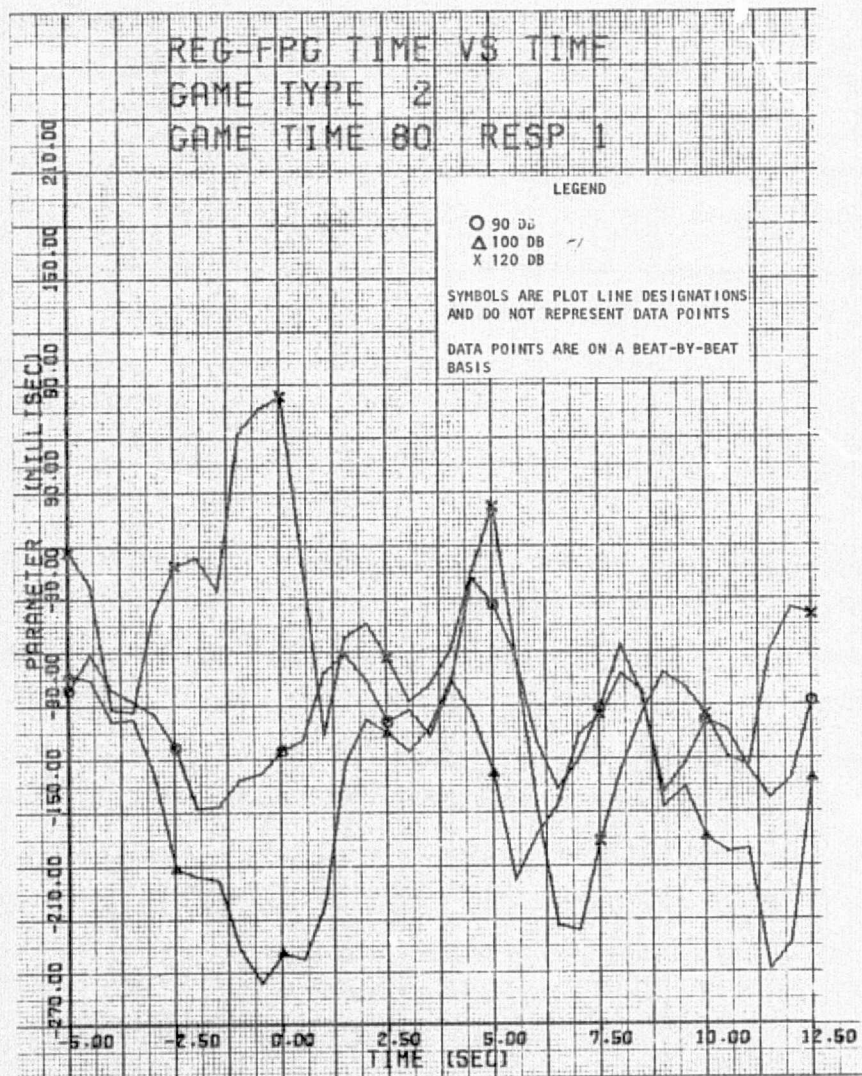
Figure 7-126. REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 1
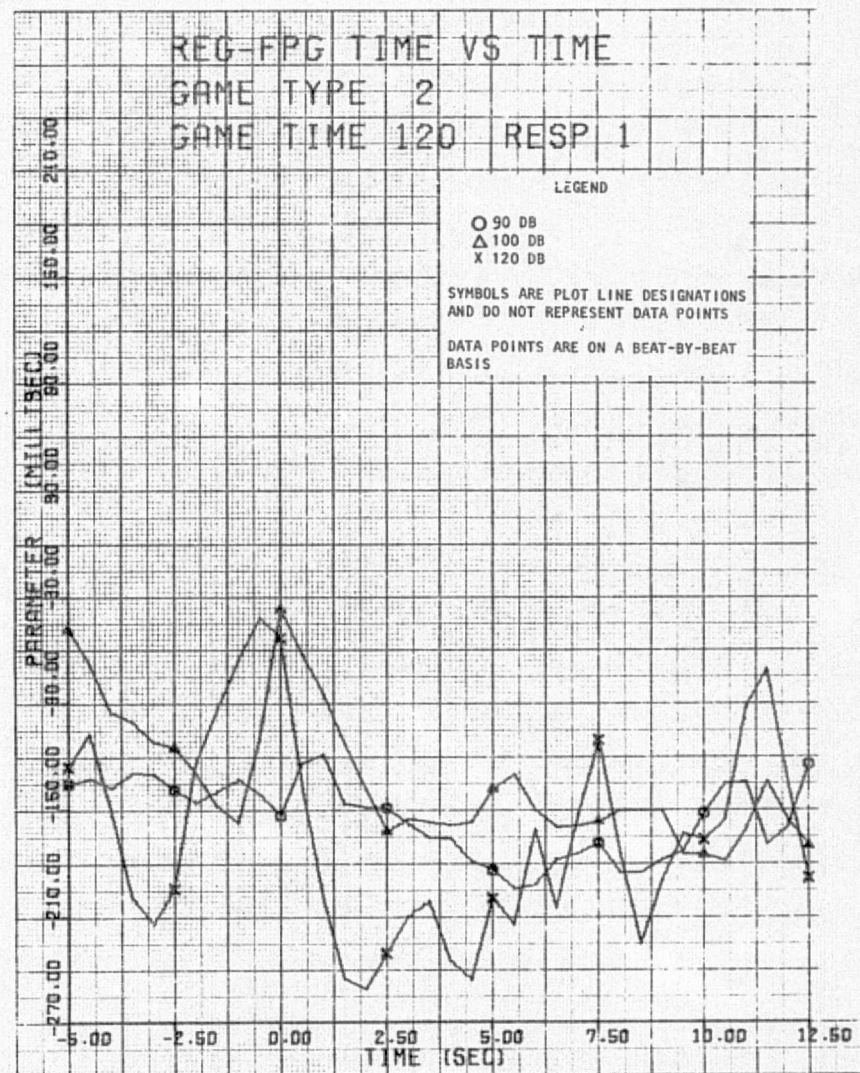
Figure 7-127. REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 1
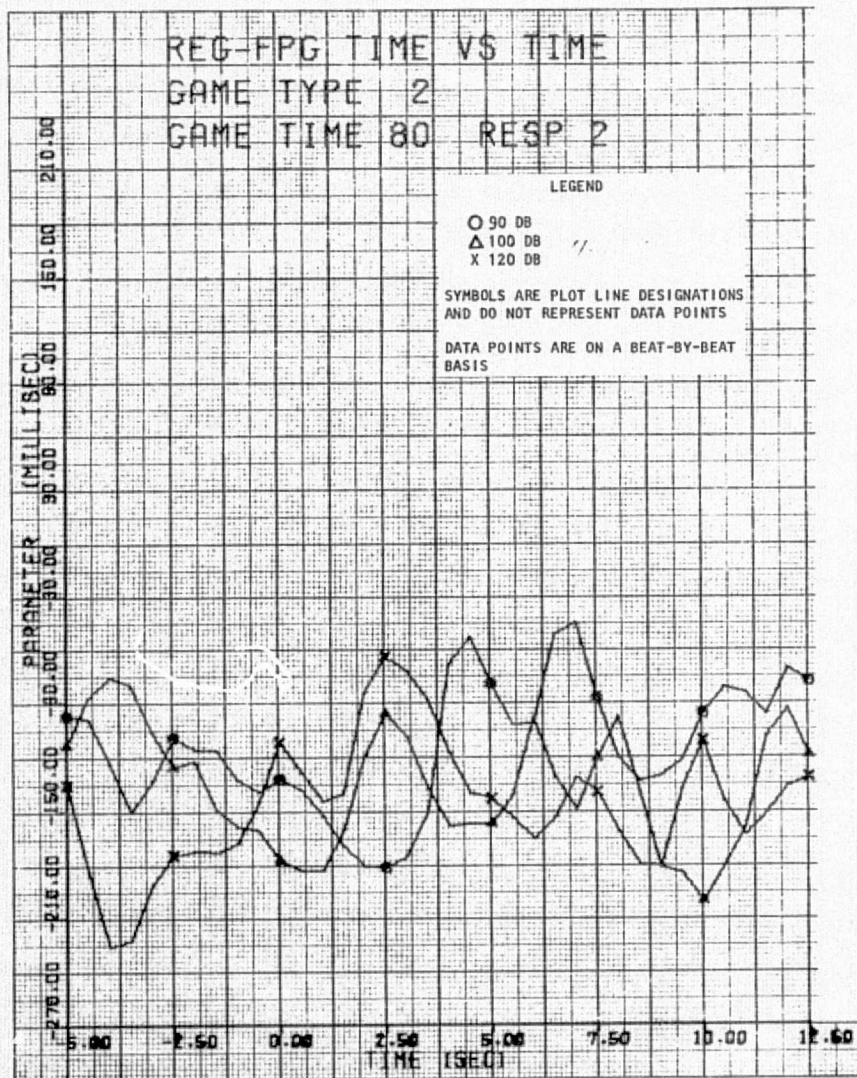
Figure 7-128.  REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 2
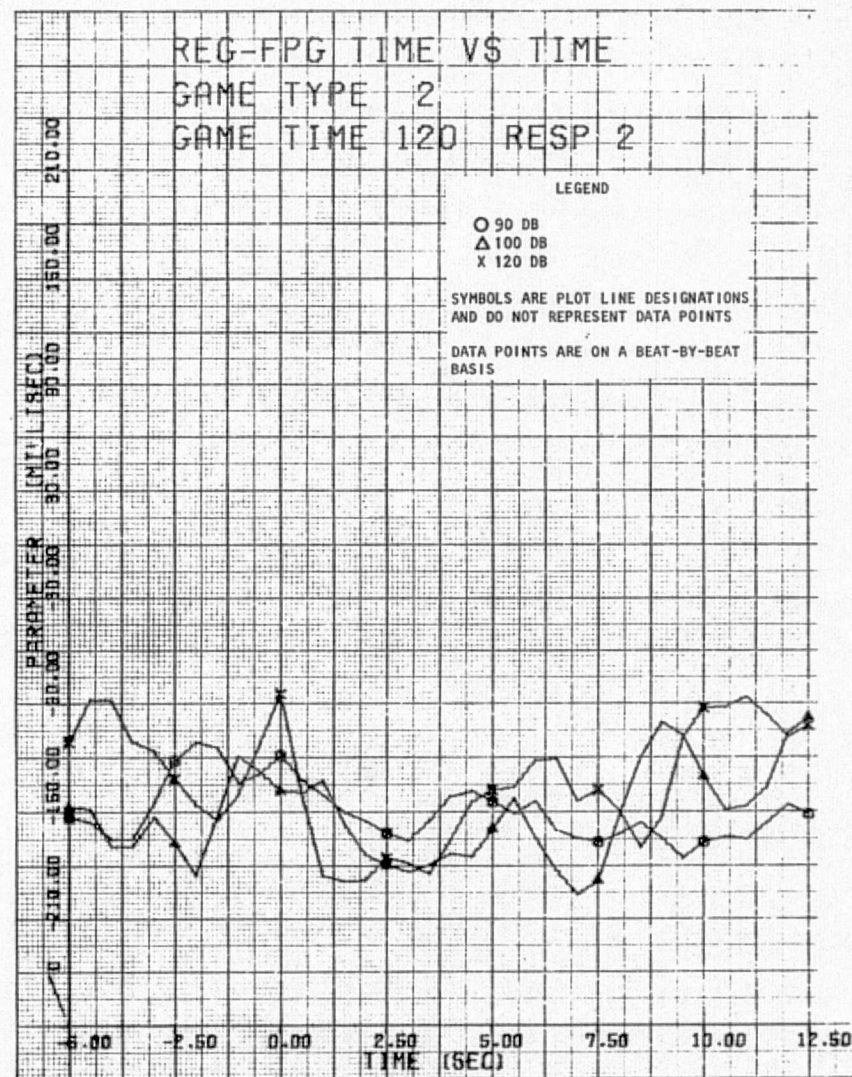


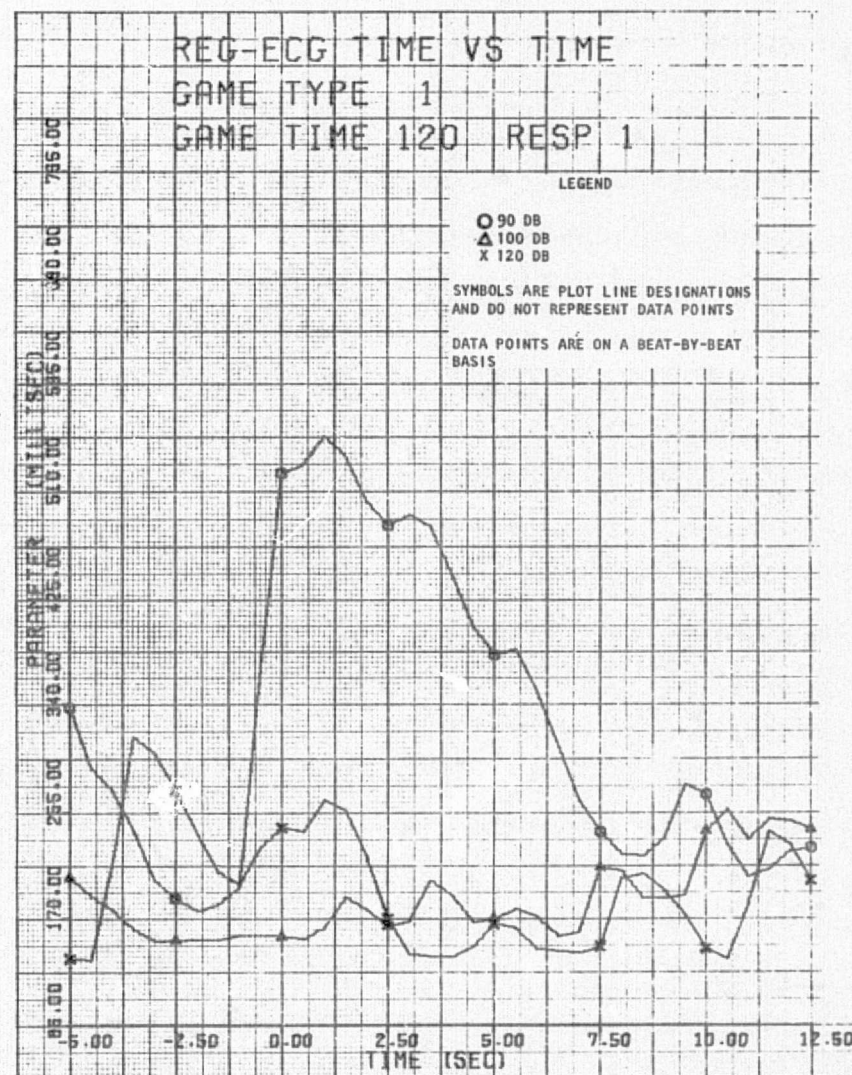Figure 7-129.  REG-FPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 2
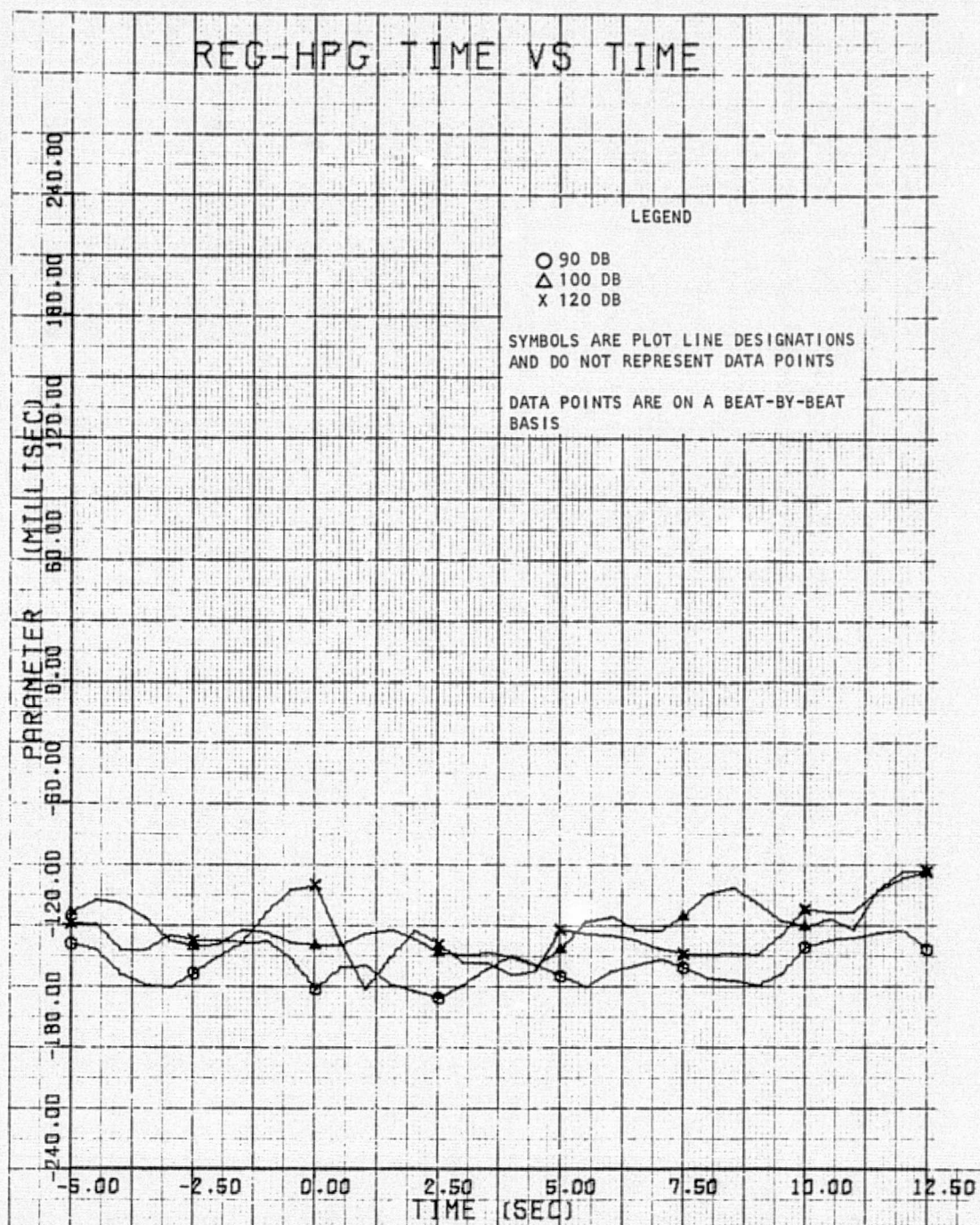
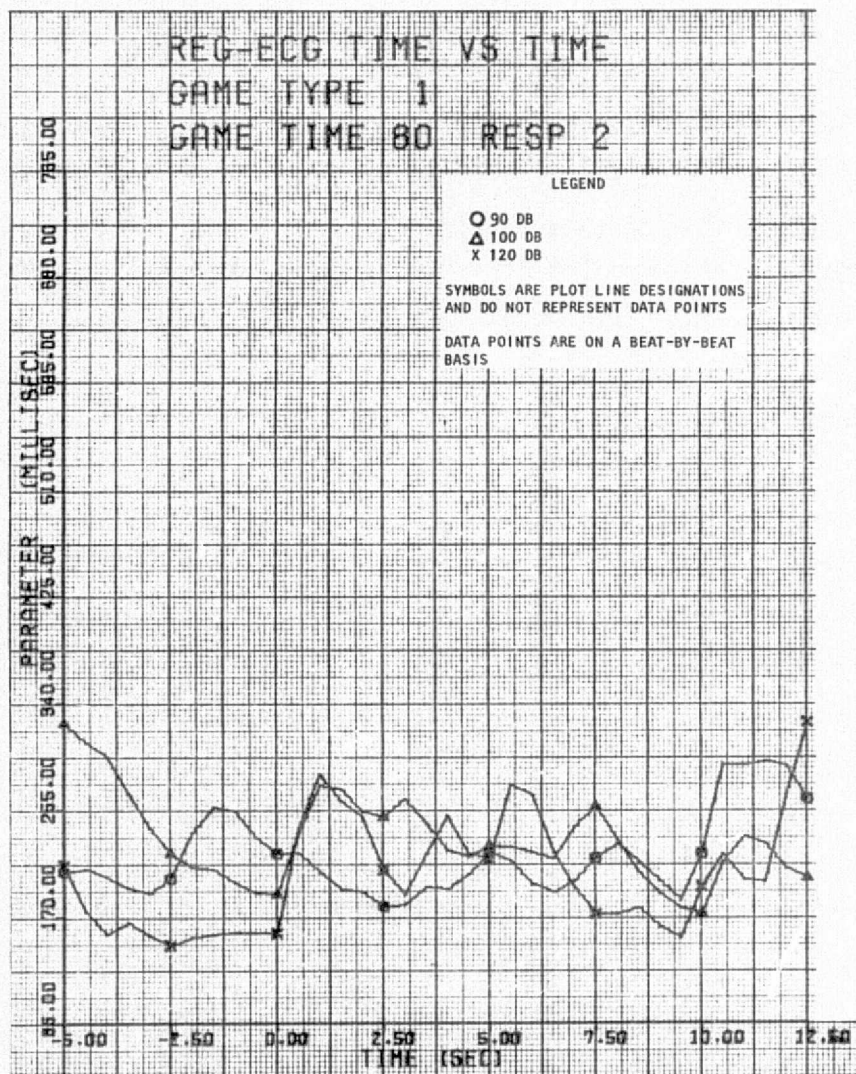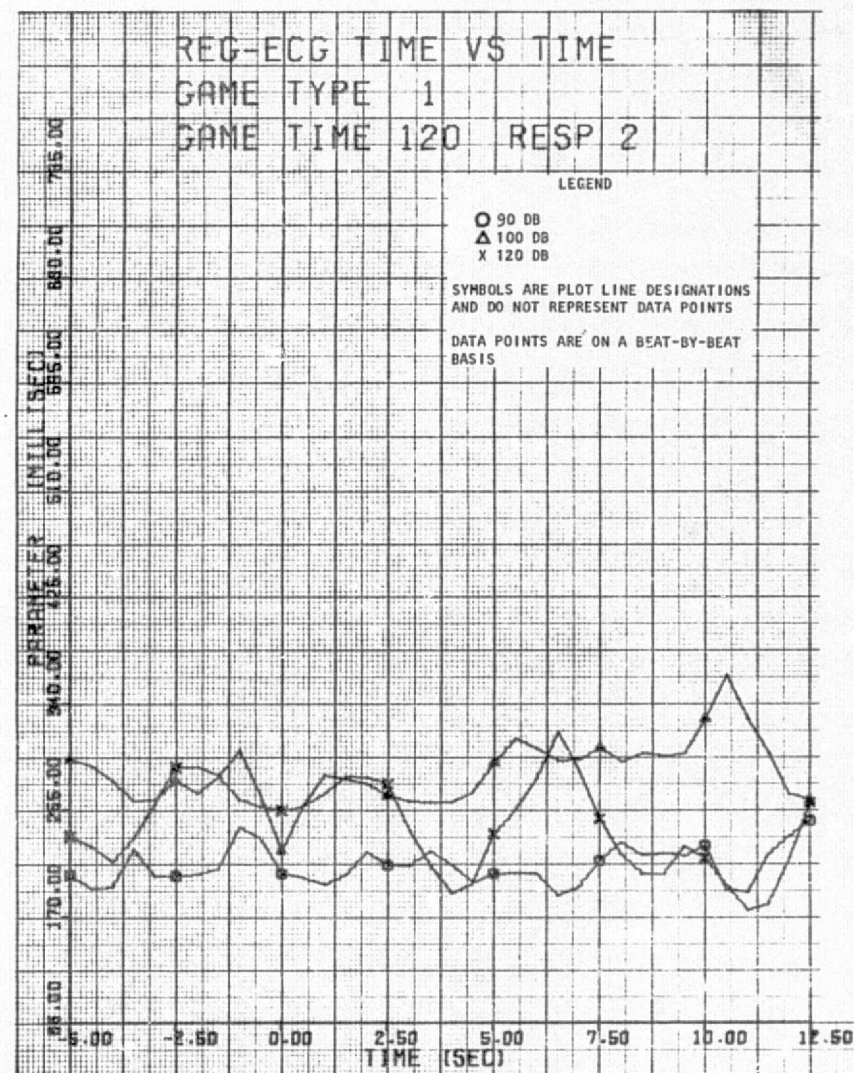Figure 7-130. REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)
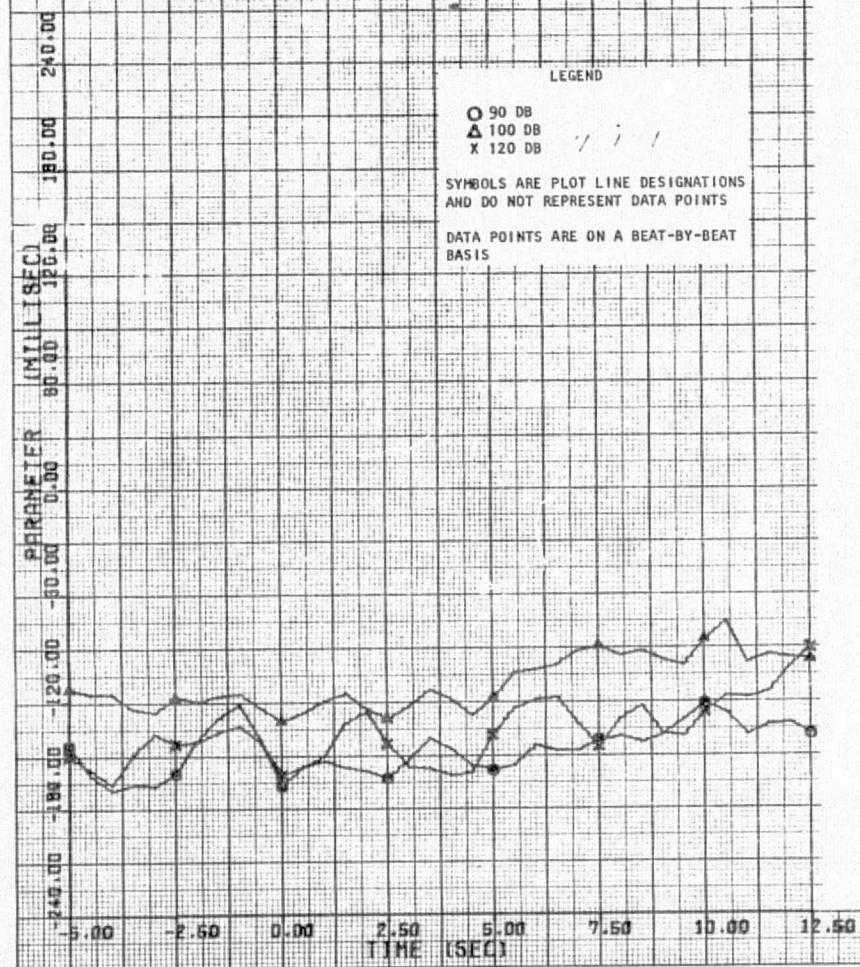
Figure 7-131.  REG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1
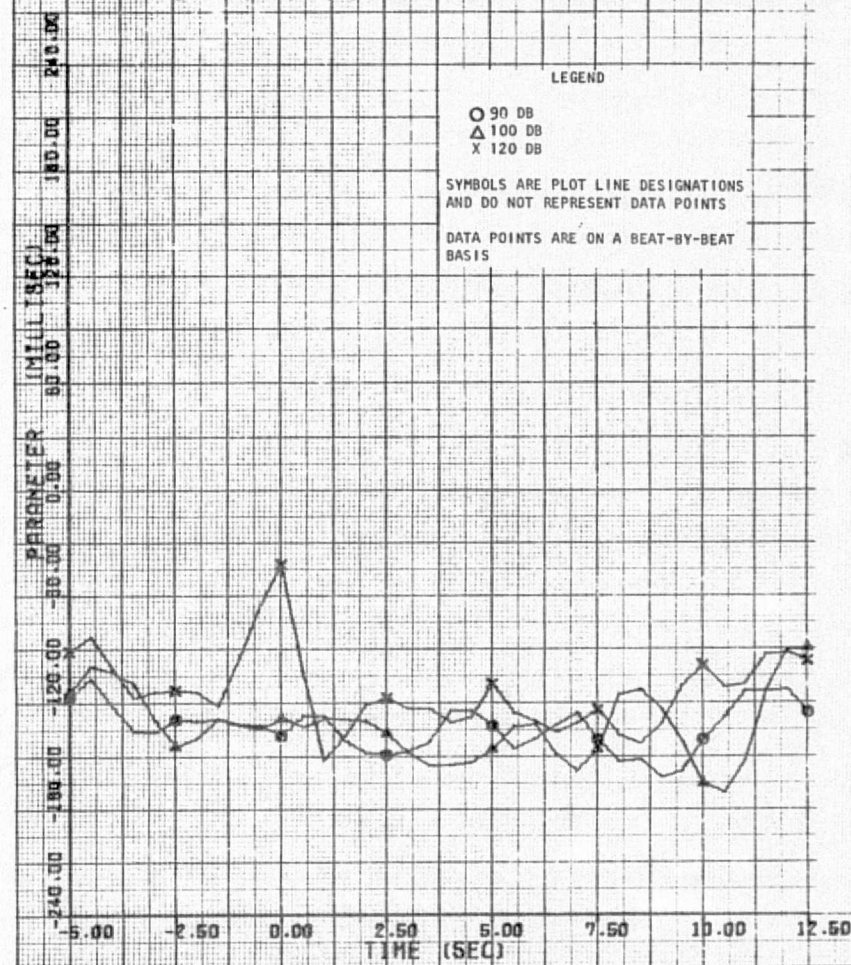


Figure 7-132.  REG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 2
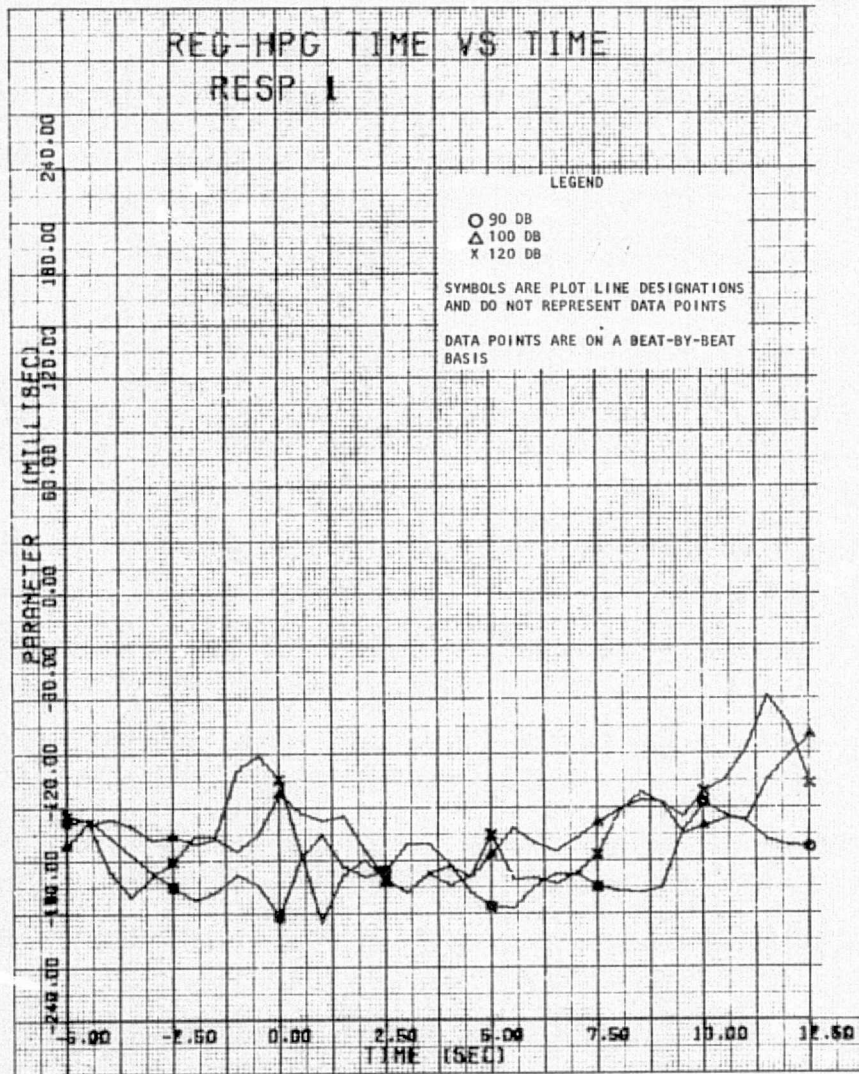
Figure 7-133. REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 1
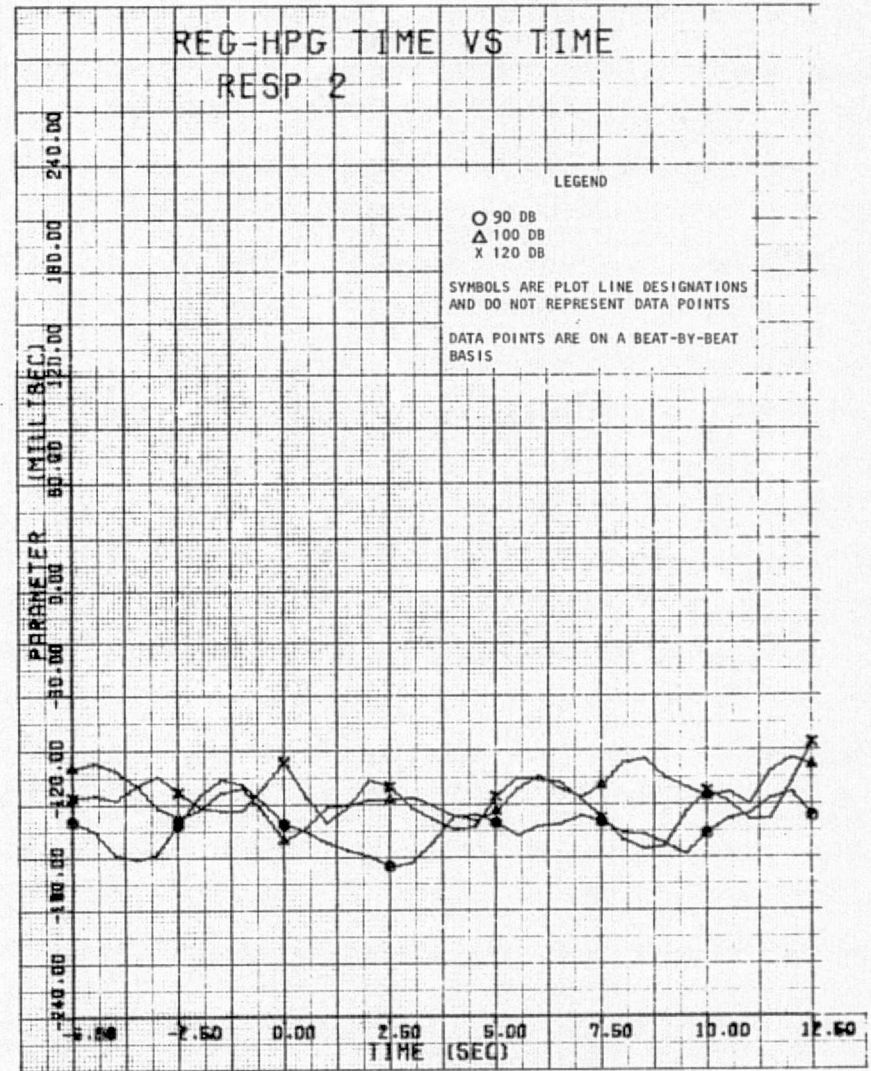
Figure 7-134. REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Response 2
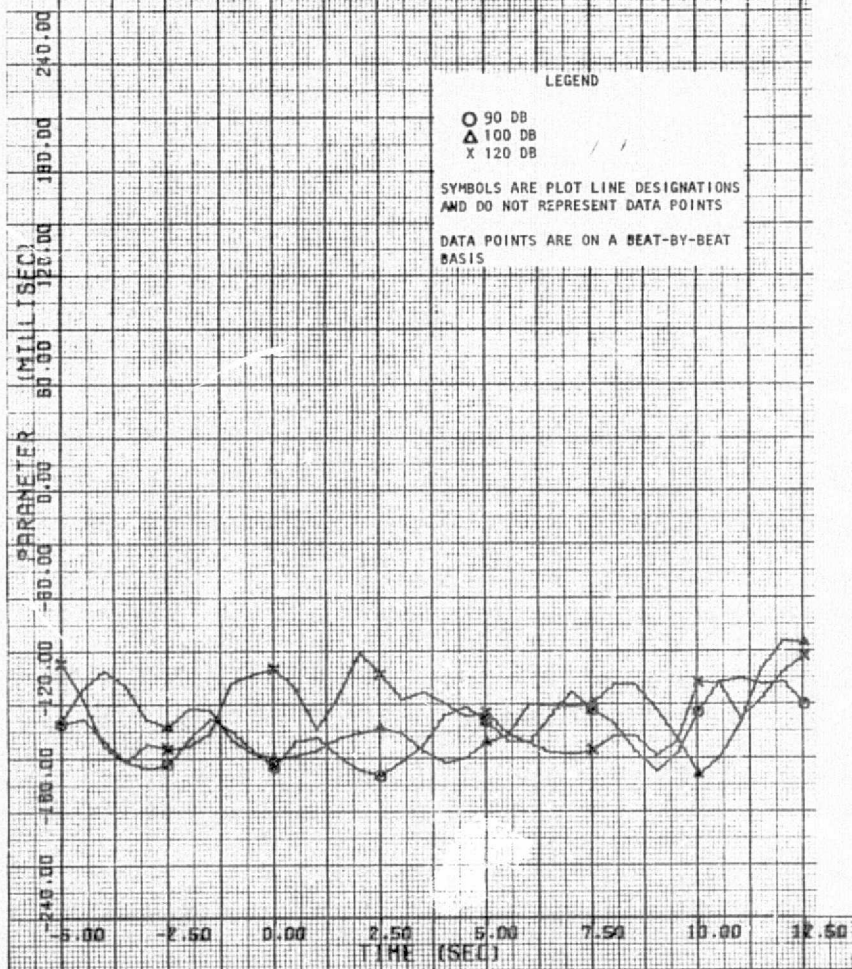
Figure 7-135.  REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--80-Sec Game Time
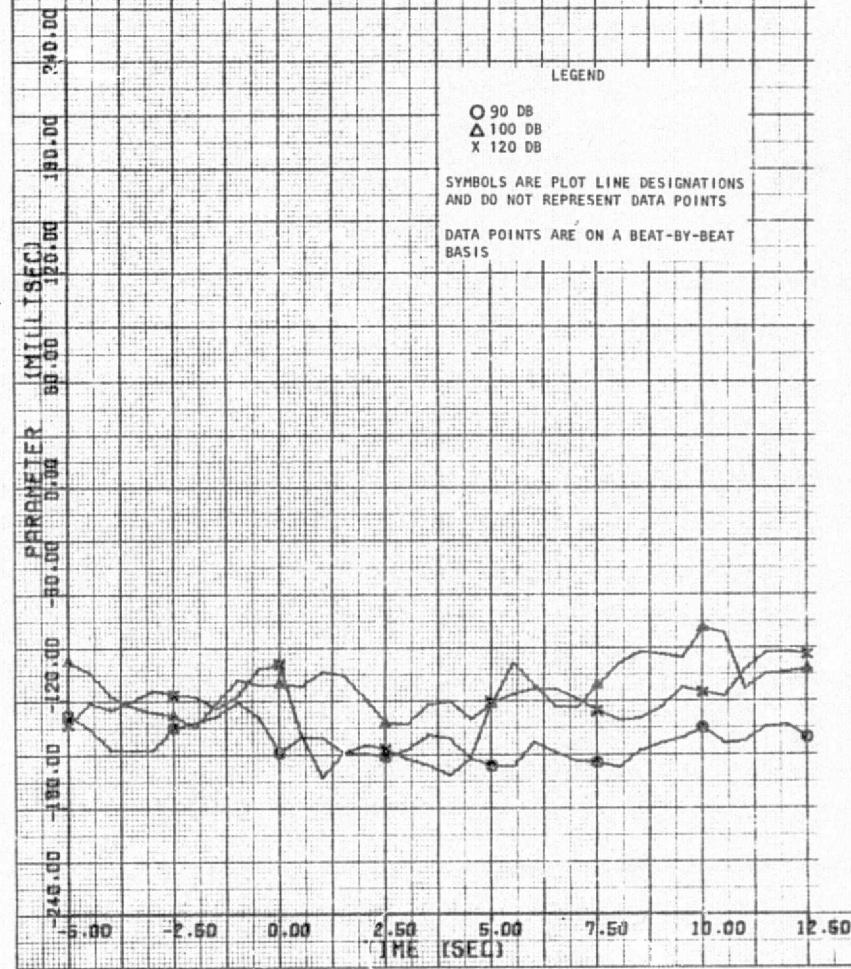


Figure 7-136.  REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--120-Sec Game Time
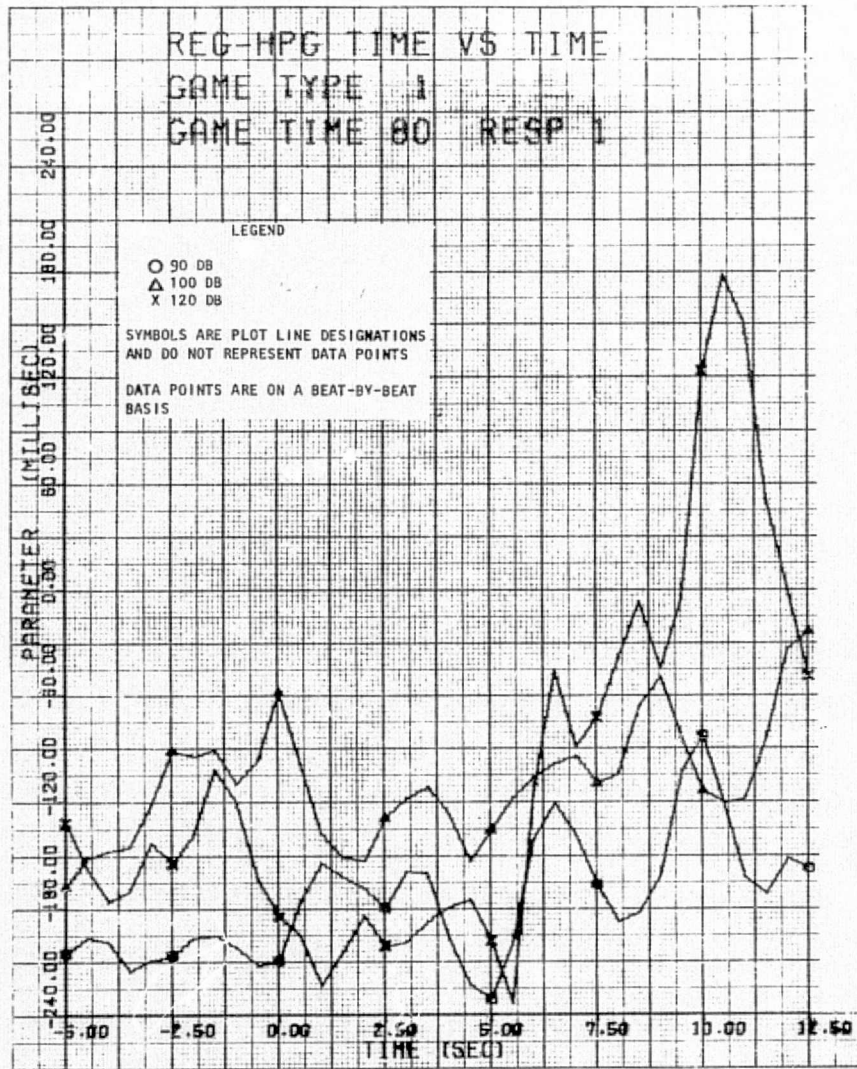
Figure 7-137.  REG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
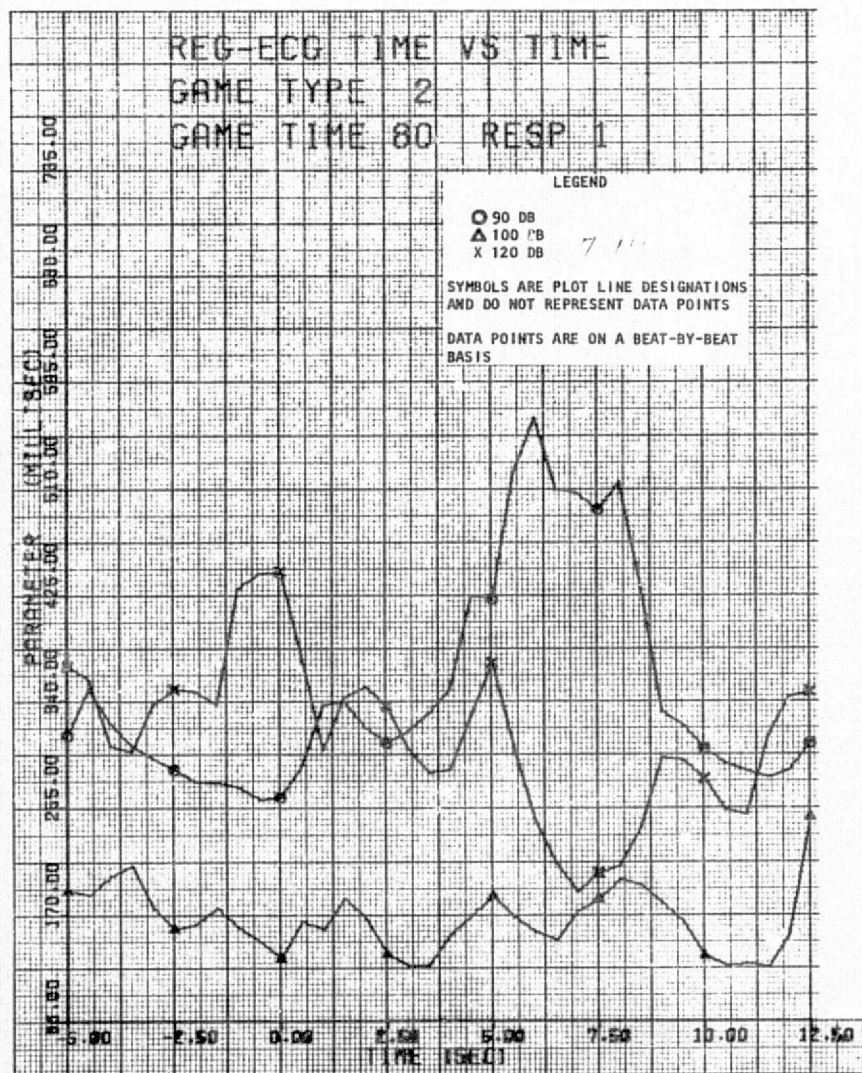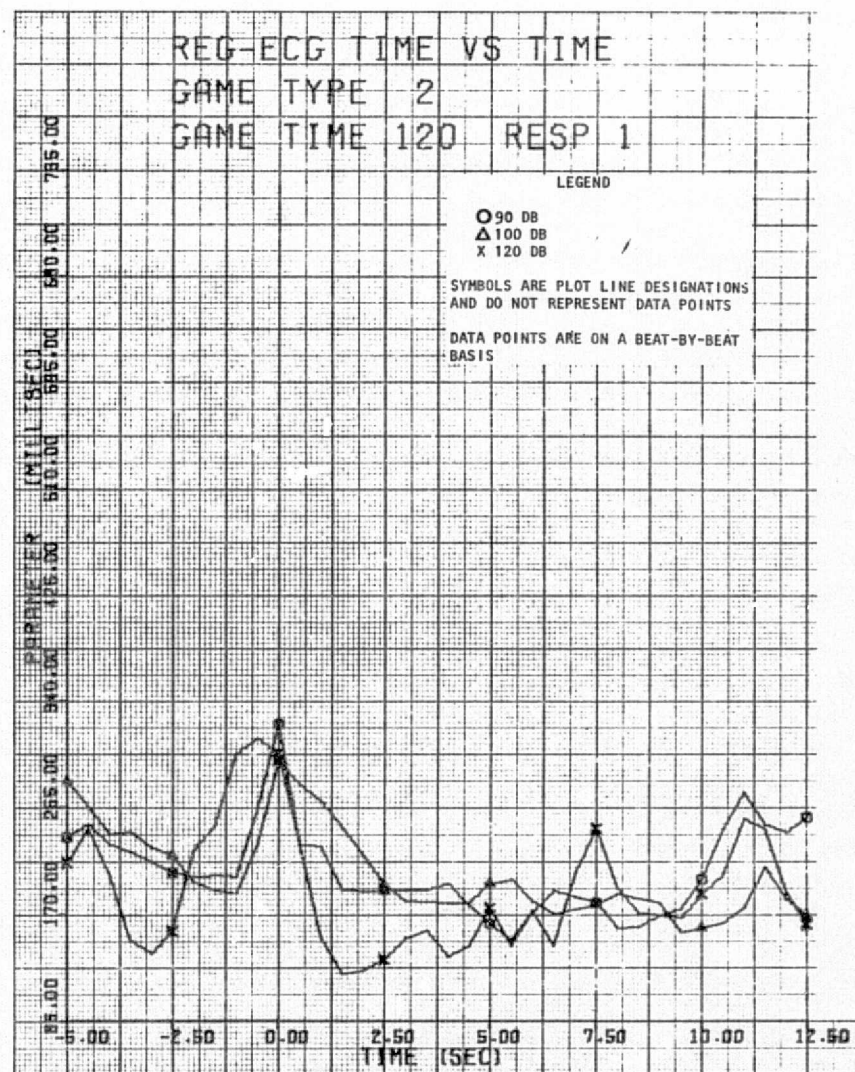Task Duration, VM Task 3)--Game Type 1,
80-Sec Game Time, Response 1
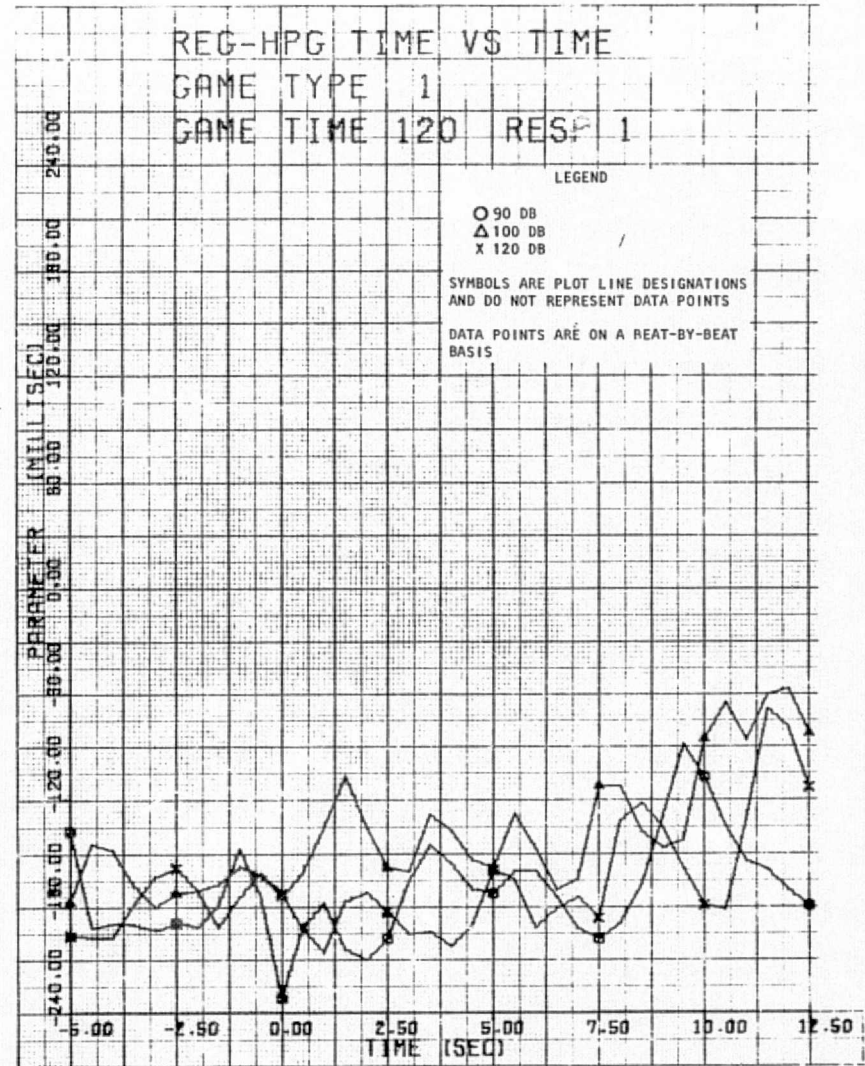
Figure 7-138.  REG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1,
120-Sec Game Time, Response 1
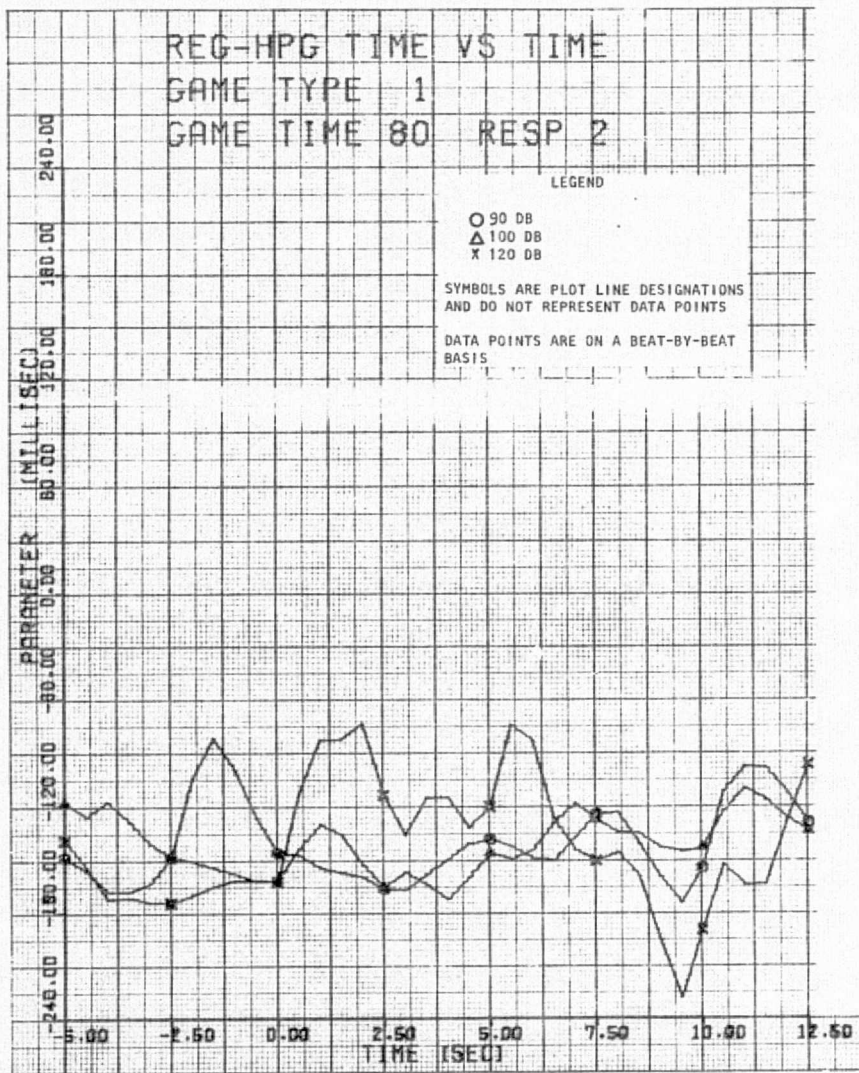
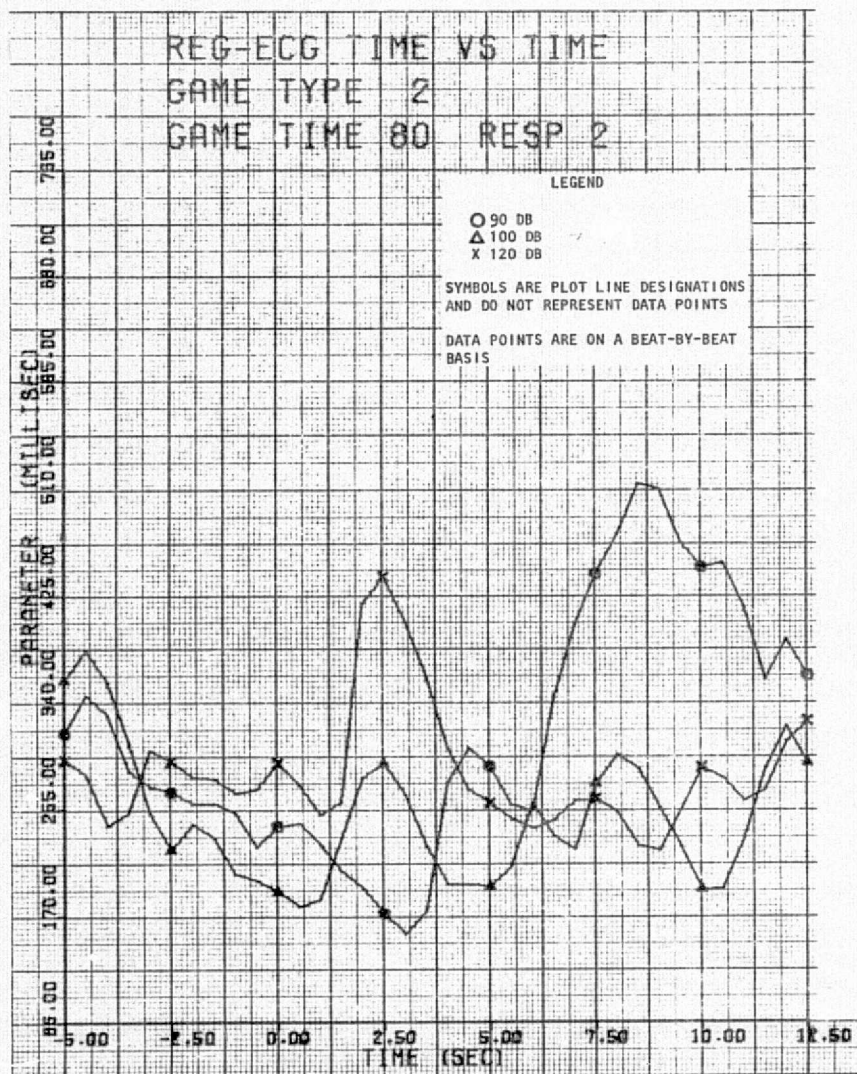Figure 7-139. REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 80-Sec Game Time, Response 2
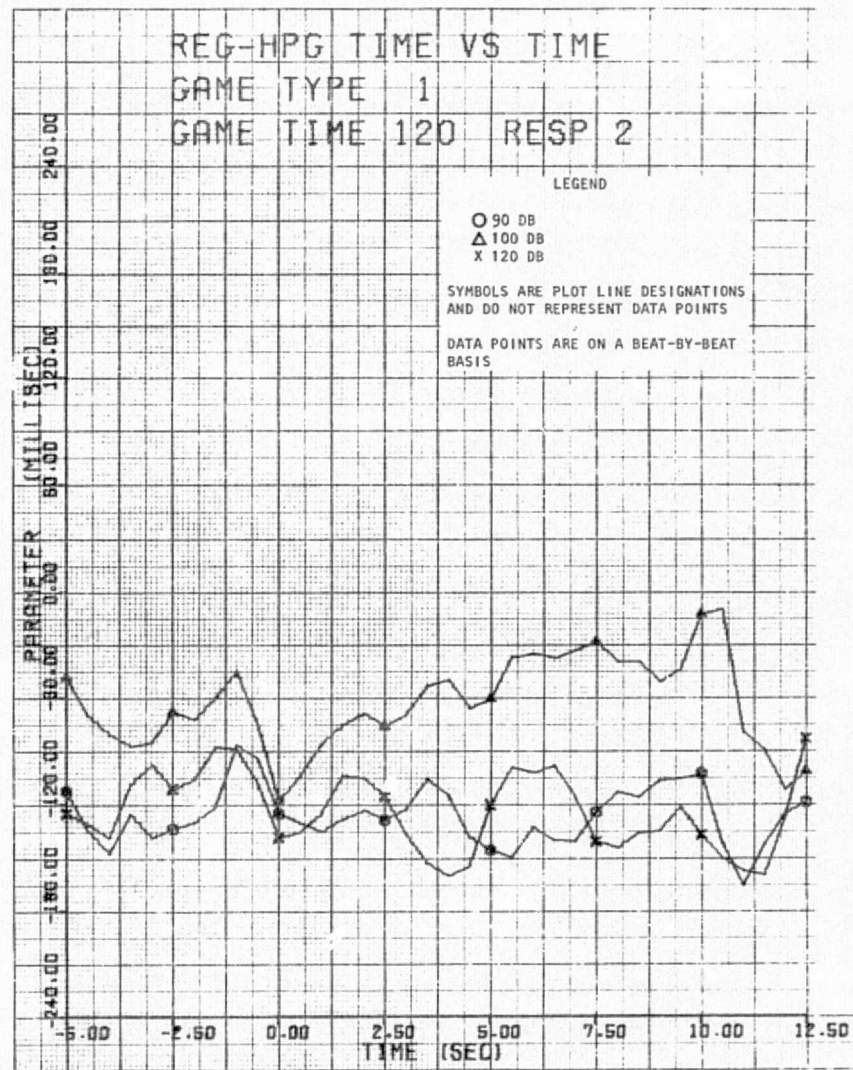
Figure 7-140. REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 120-Sec Game Time, Response 2
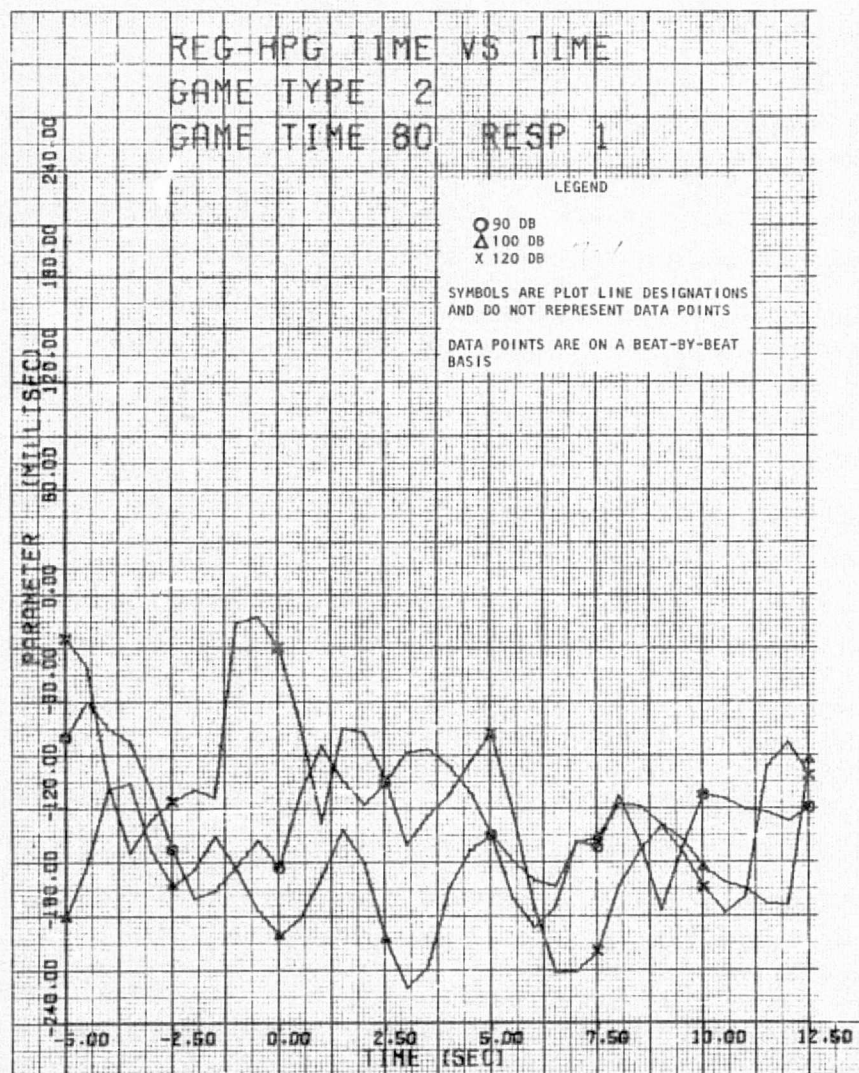
Figure 7-141.  REG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 2,
80-Sec Game Time, Response 1
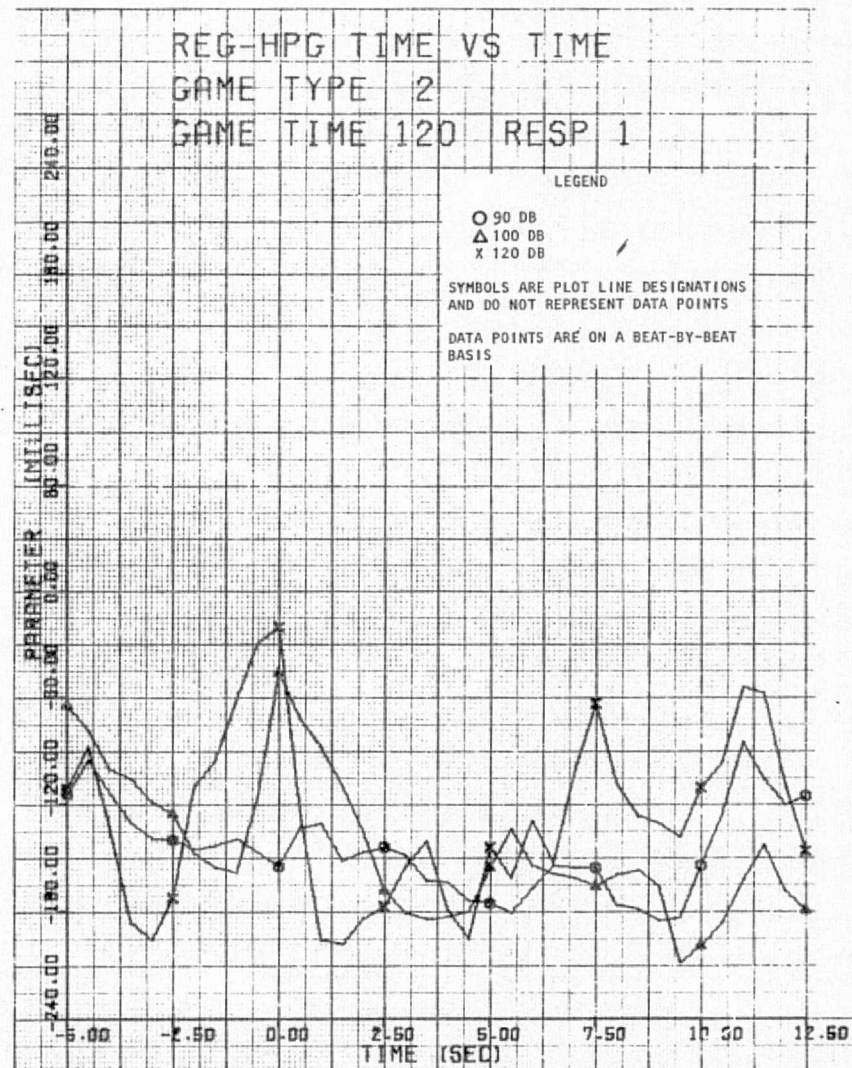
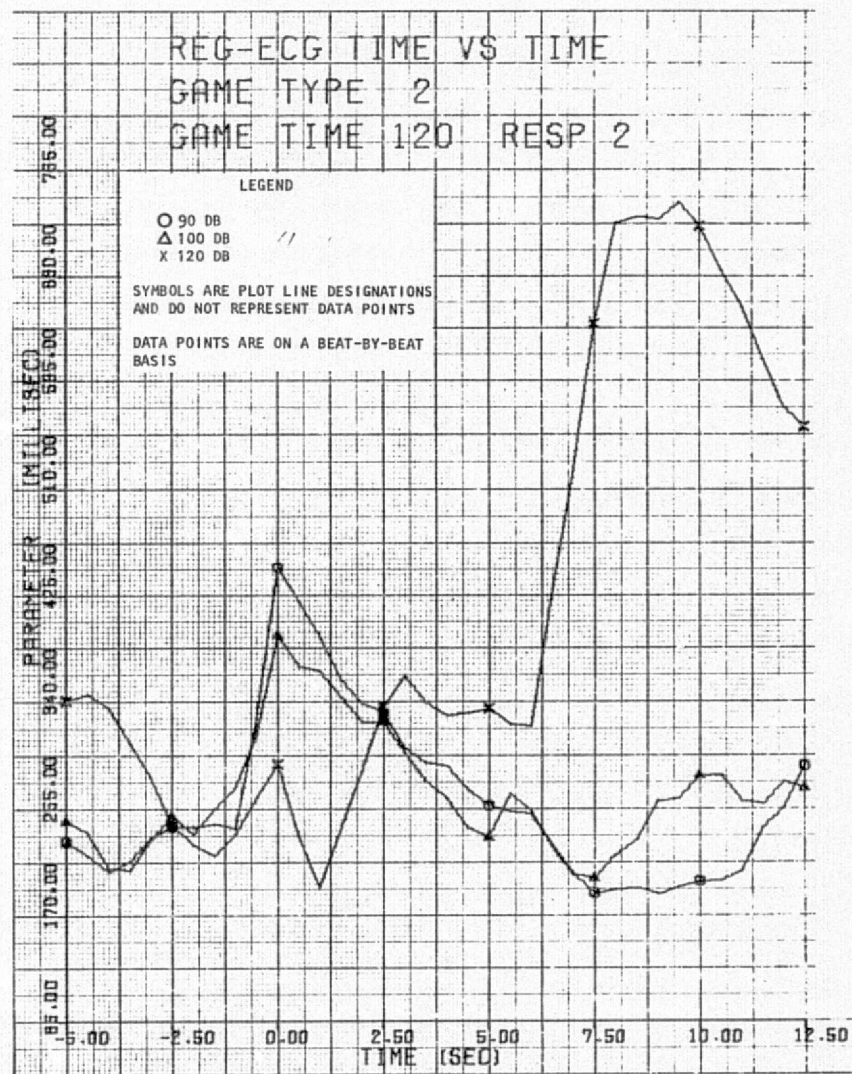Figure 7-142.  REG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 2,
120-Sec Game Time, Response 1
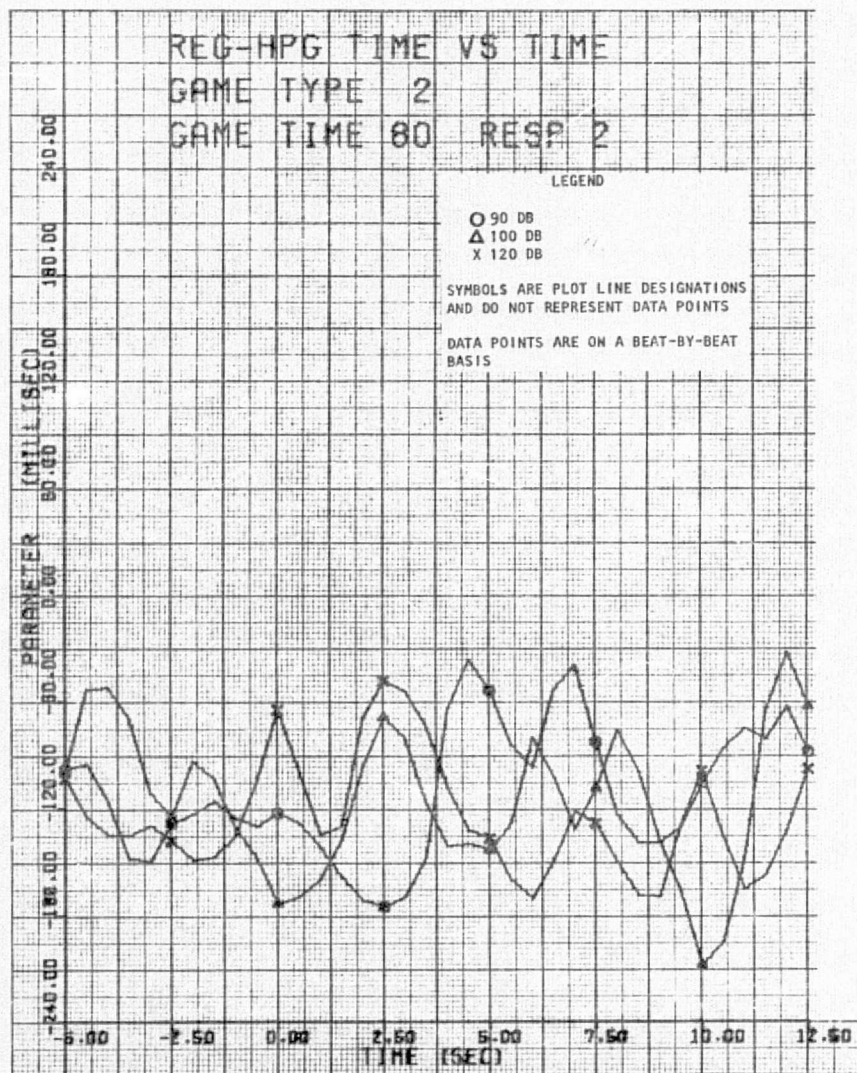
Figure 7-143. REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 2
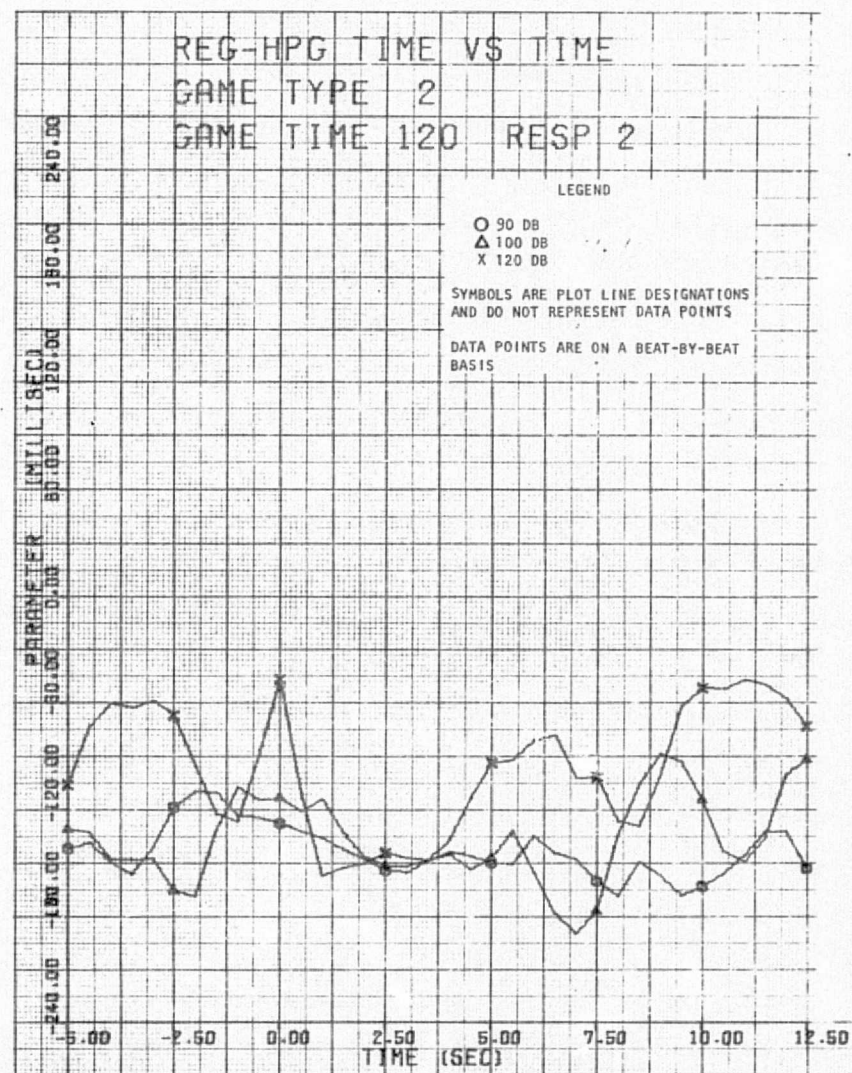
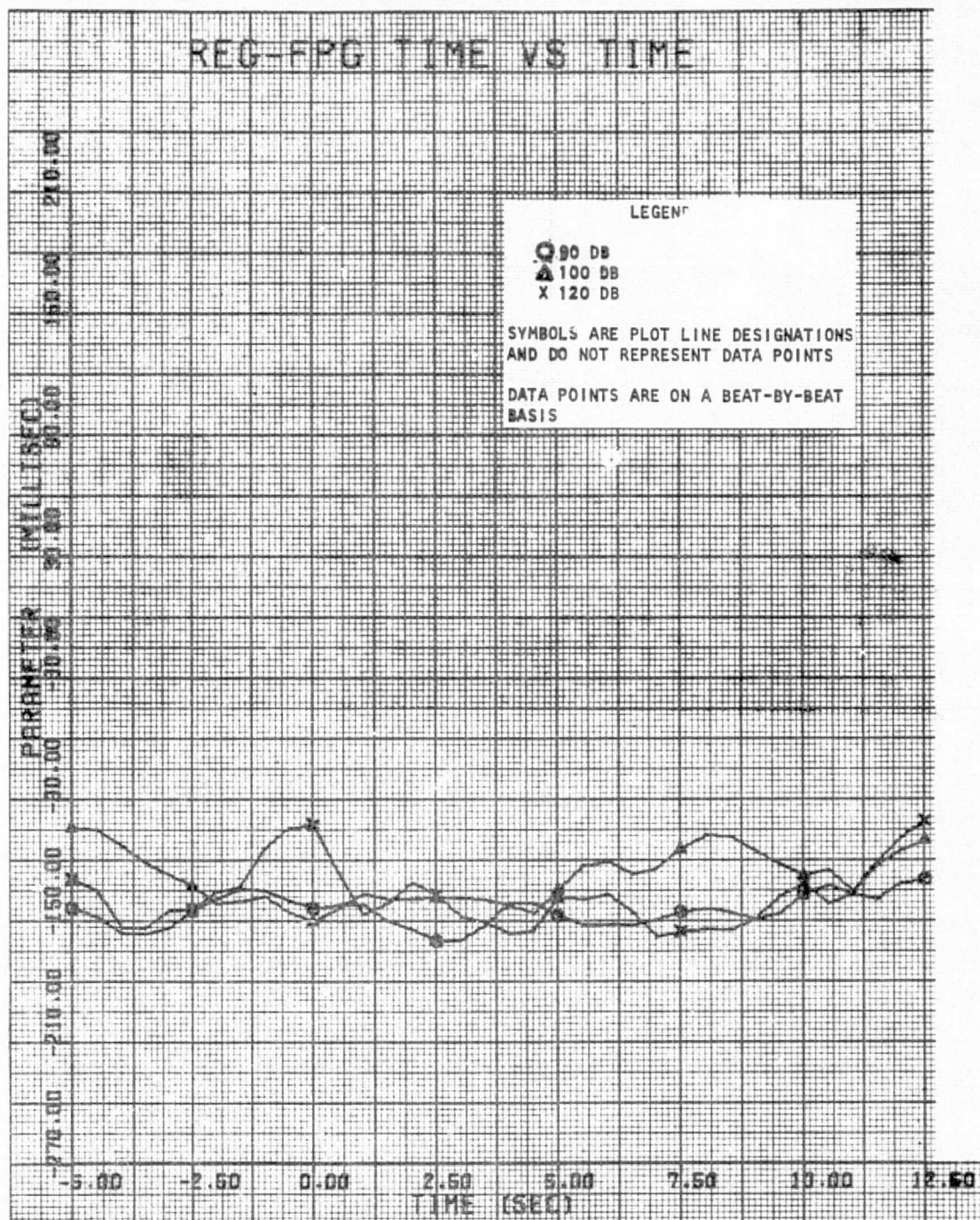Figure 7-144. REG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 2
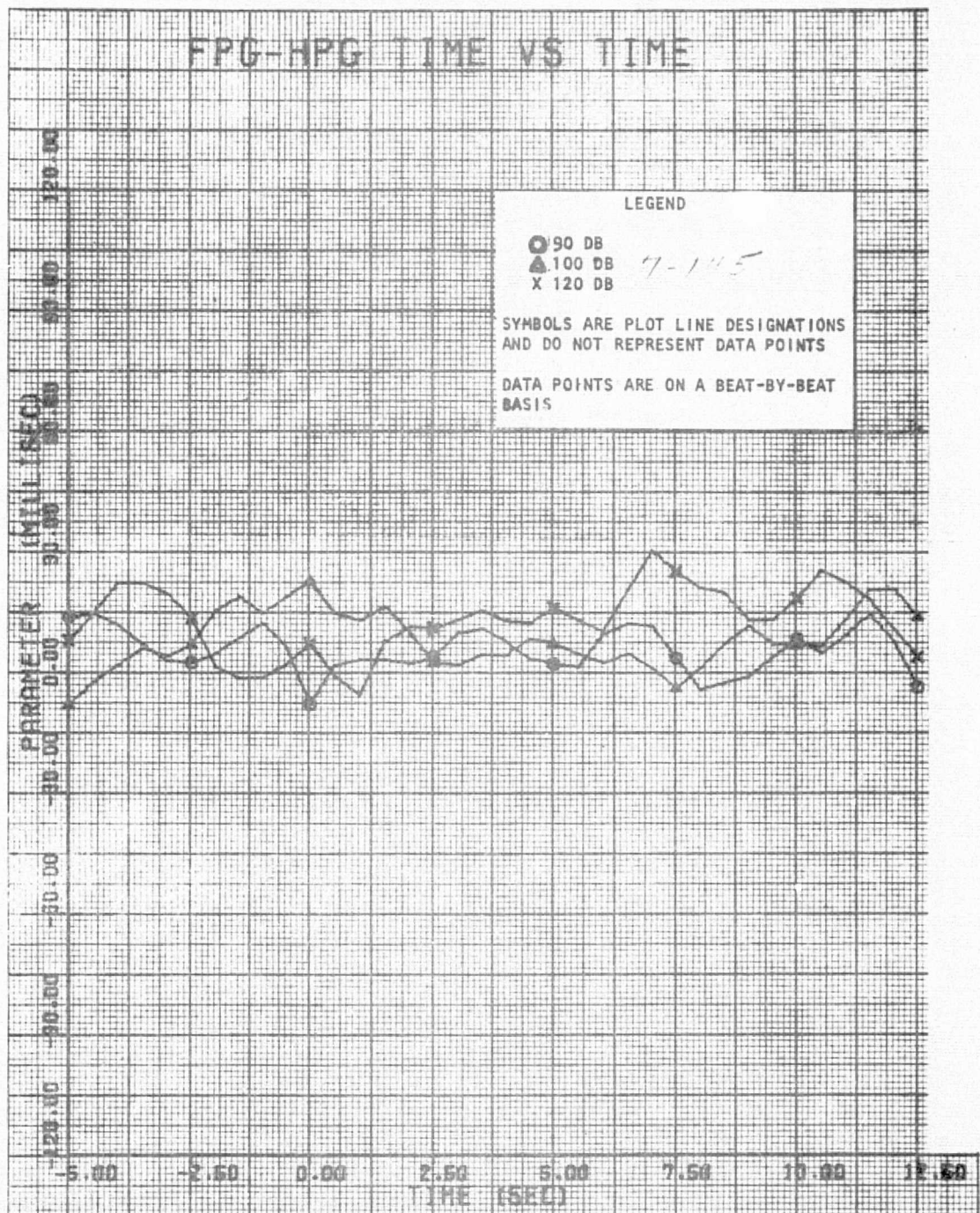
Figure 7-145. FPG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
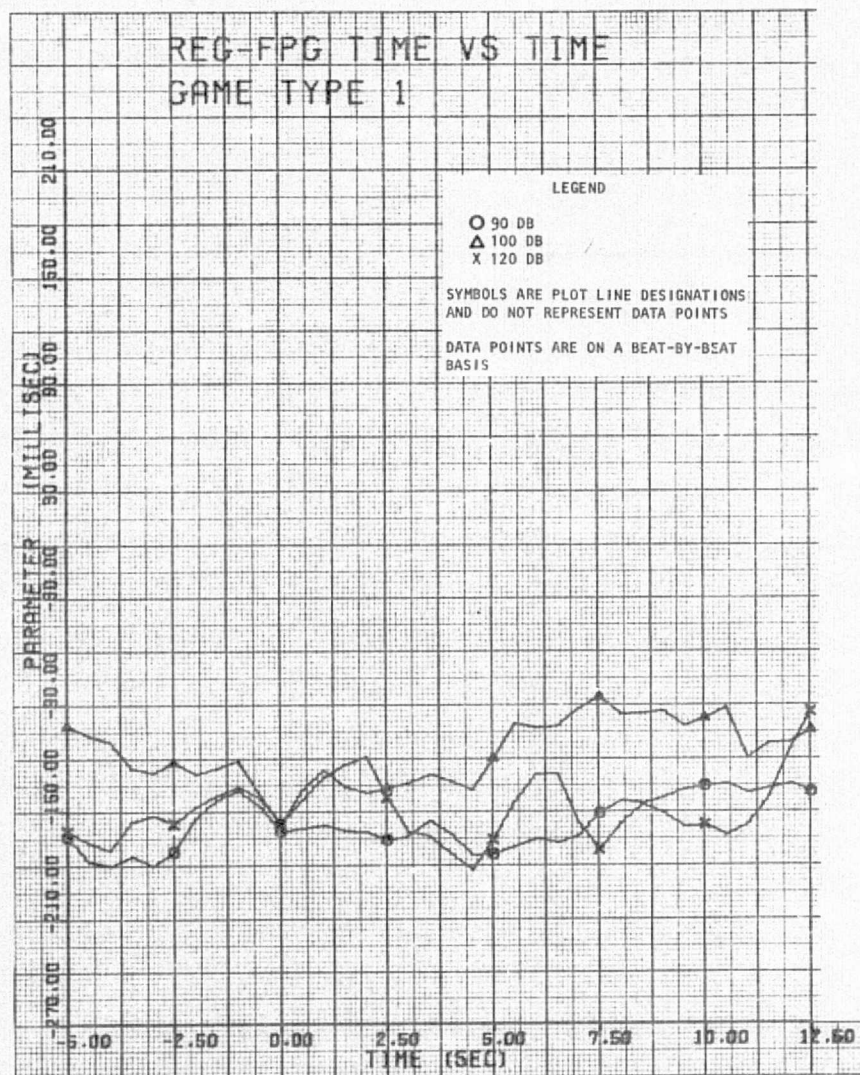Task Duration, VM Task 3)
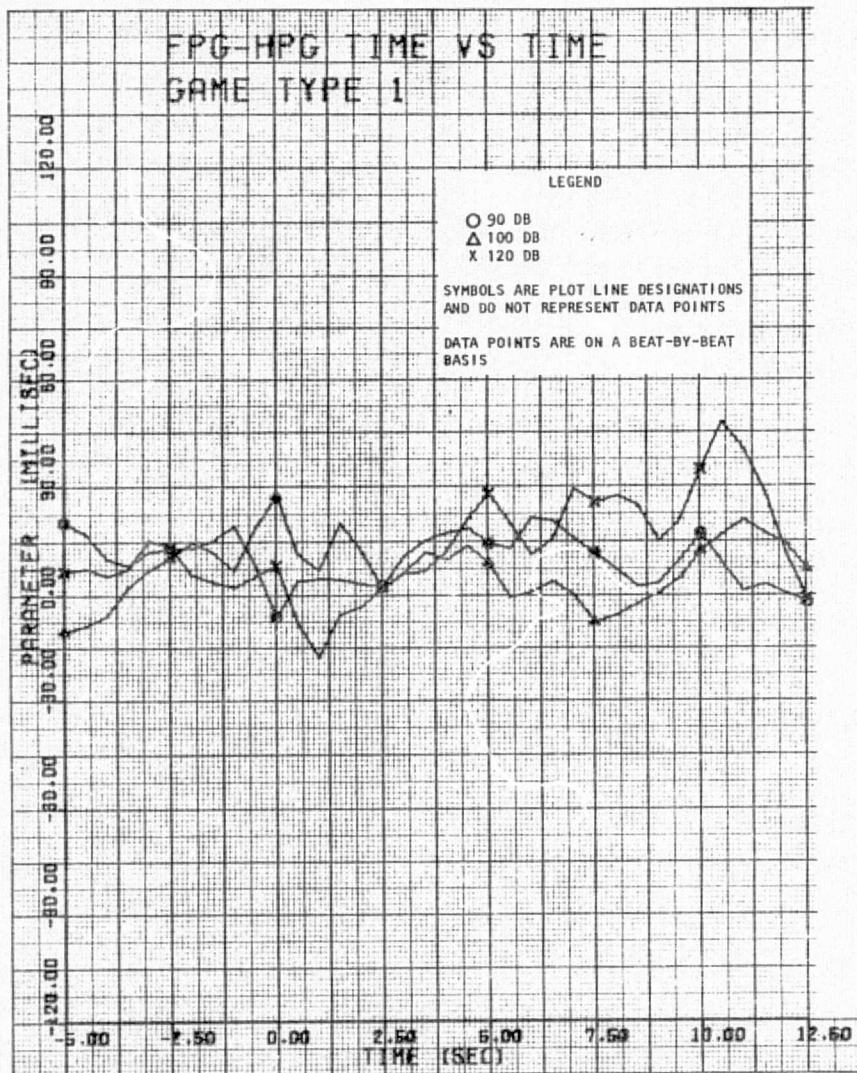
Figure 7-146. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1,
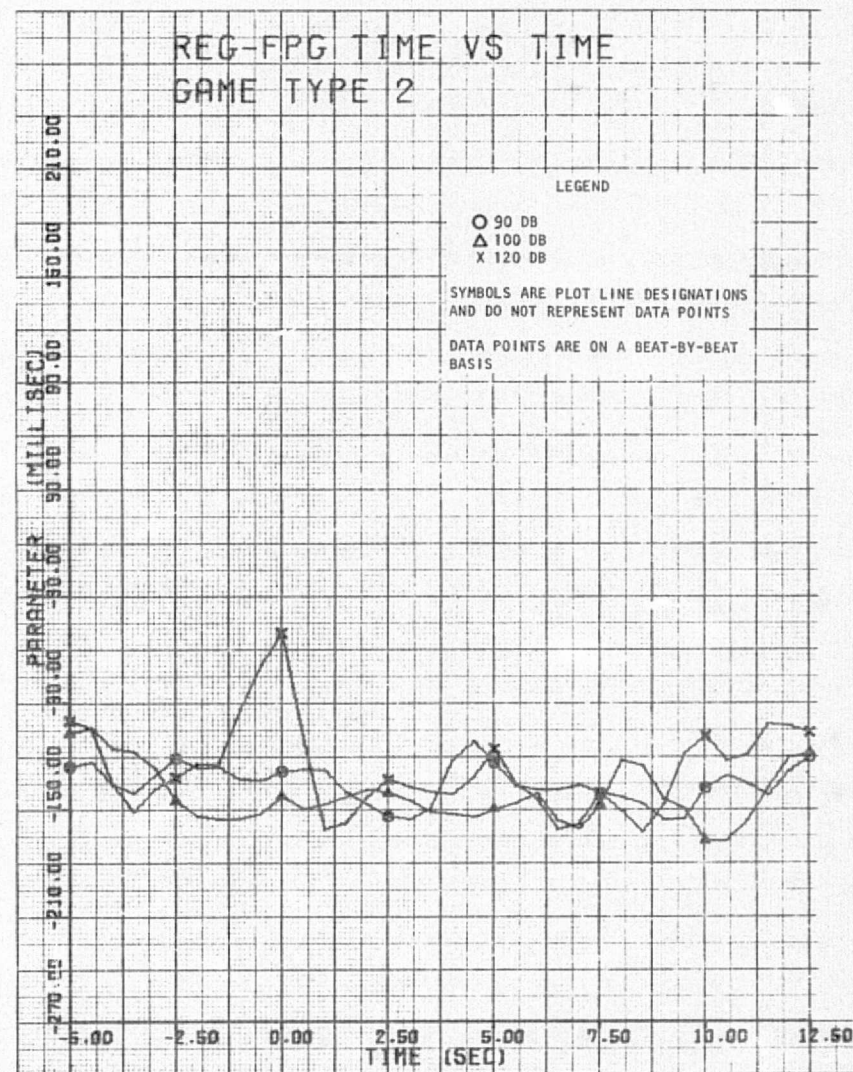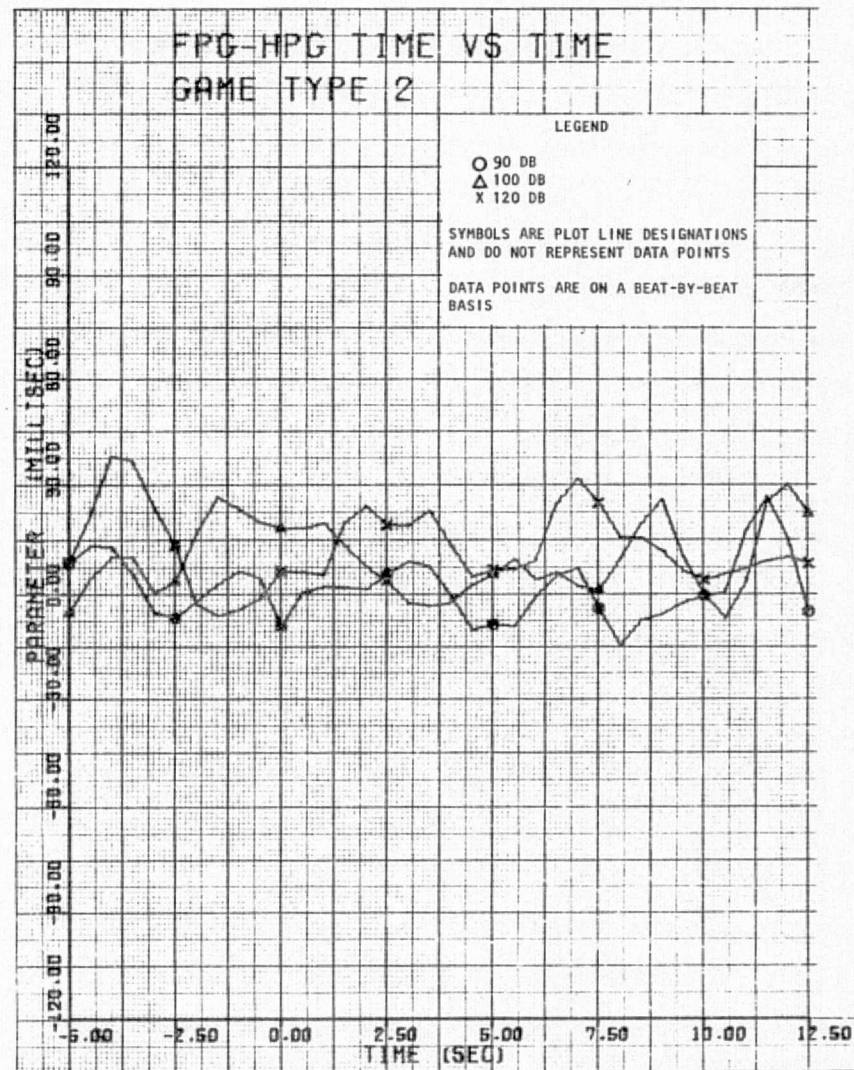


Figure 7-147. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2
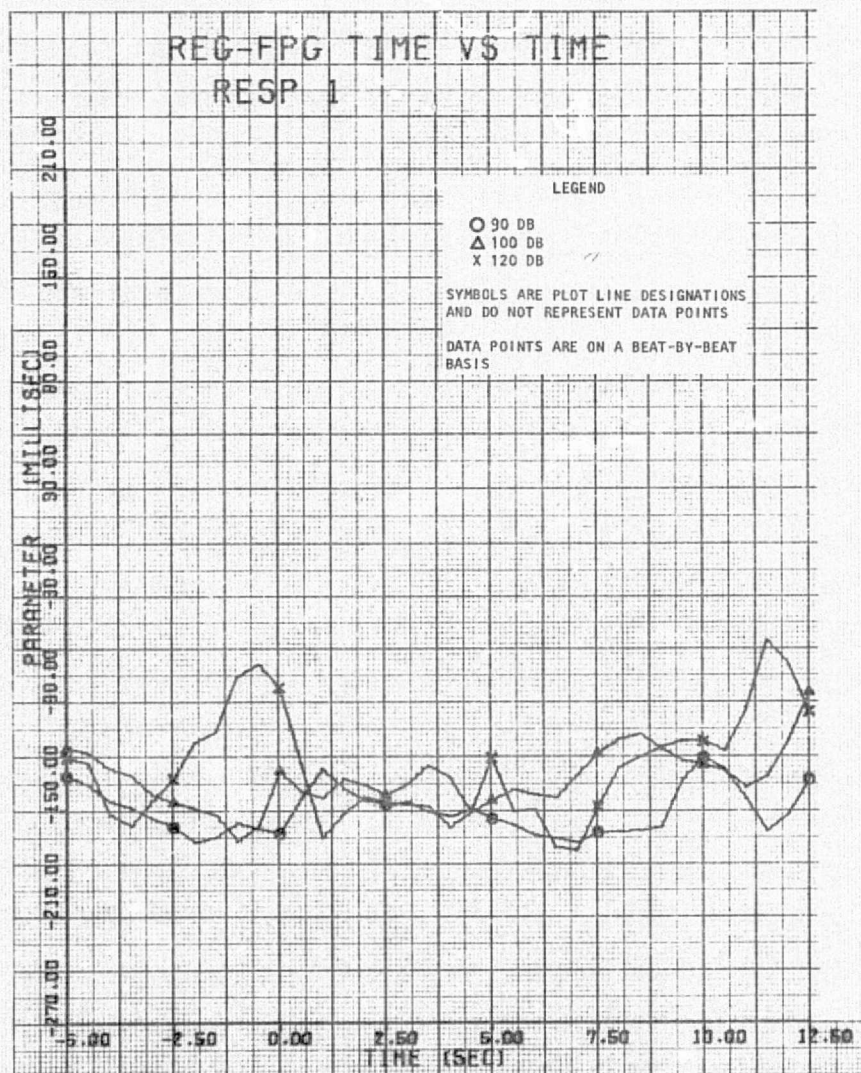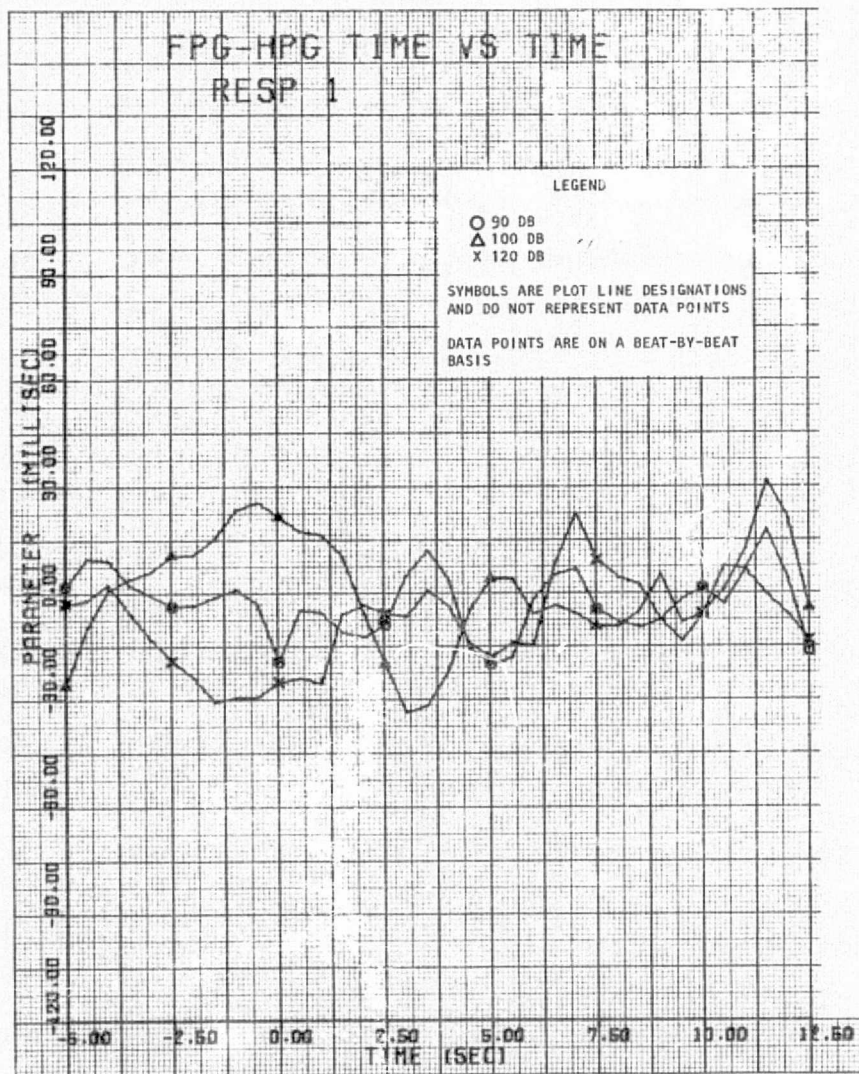
Figure 7-148.    FPG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
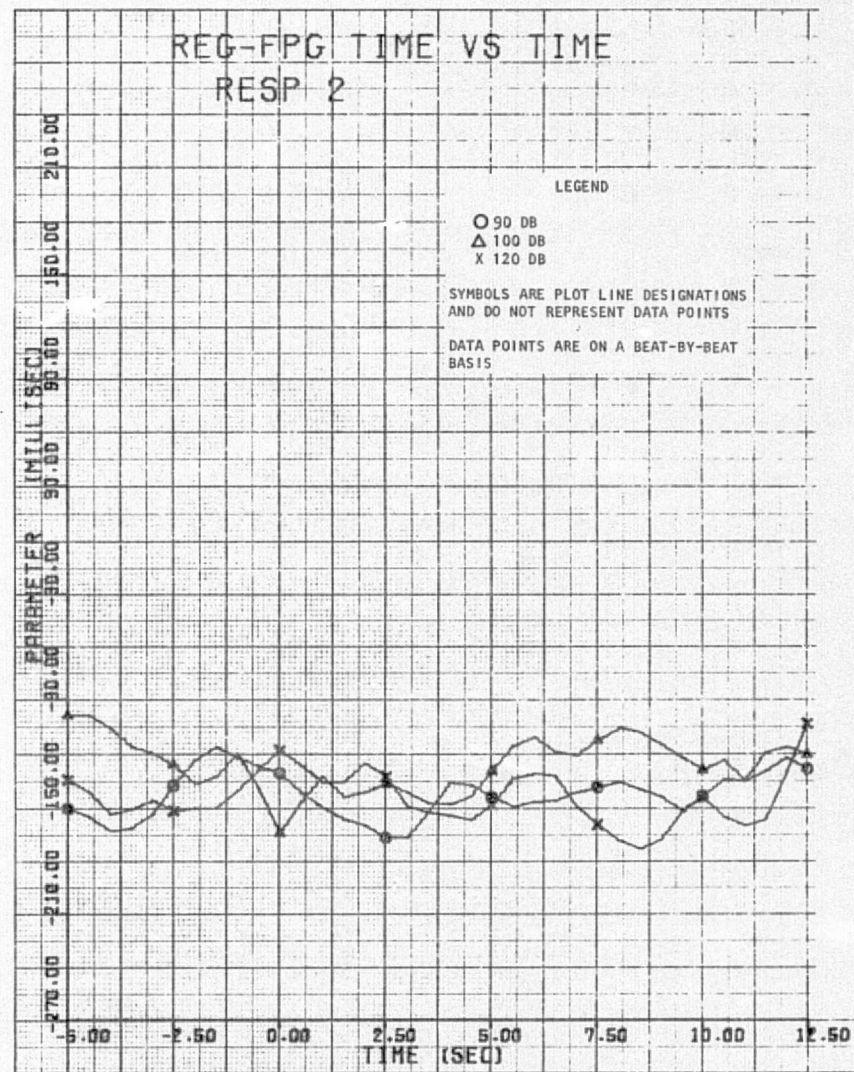Task Duration, VM Task 3)--Response 1
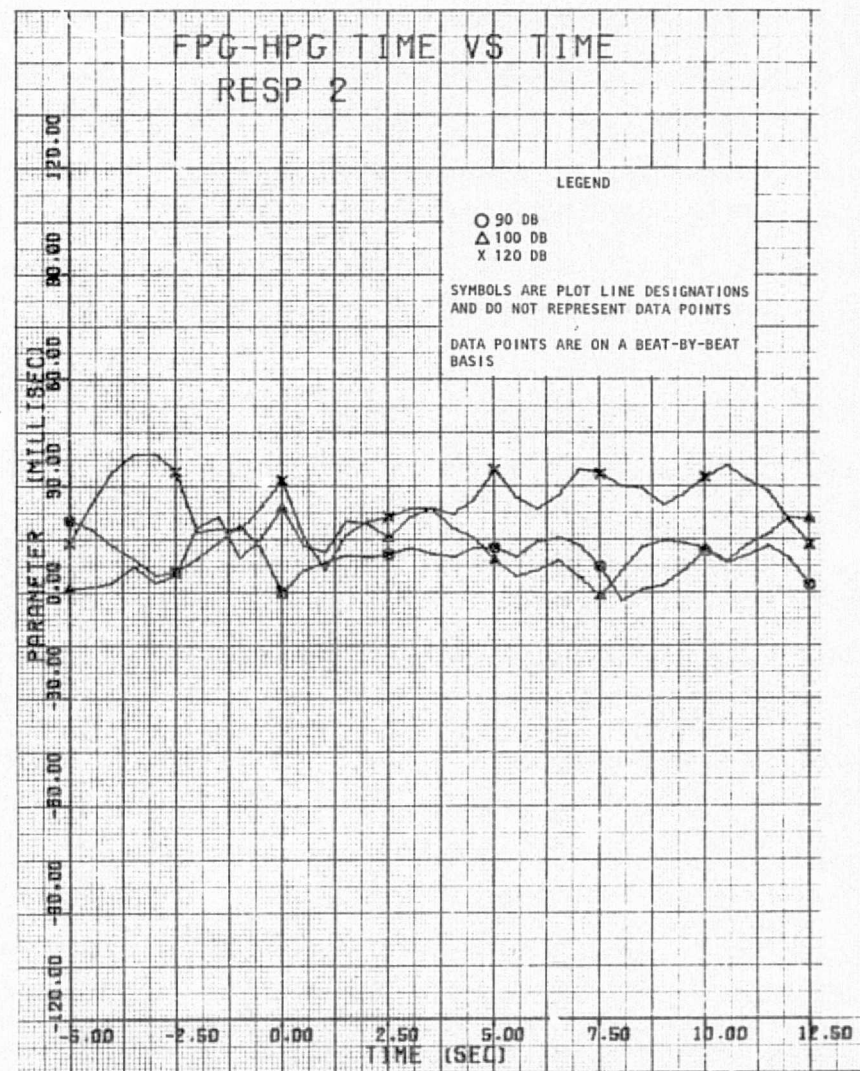


Figure 7-149.    FPG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
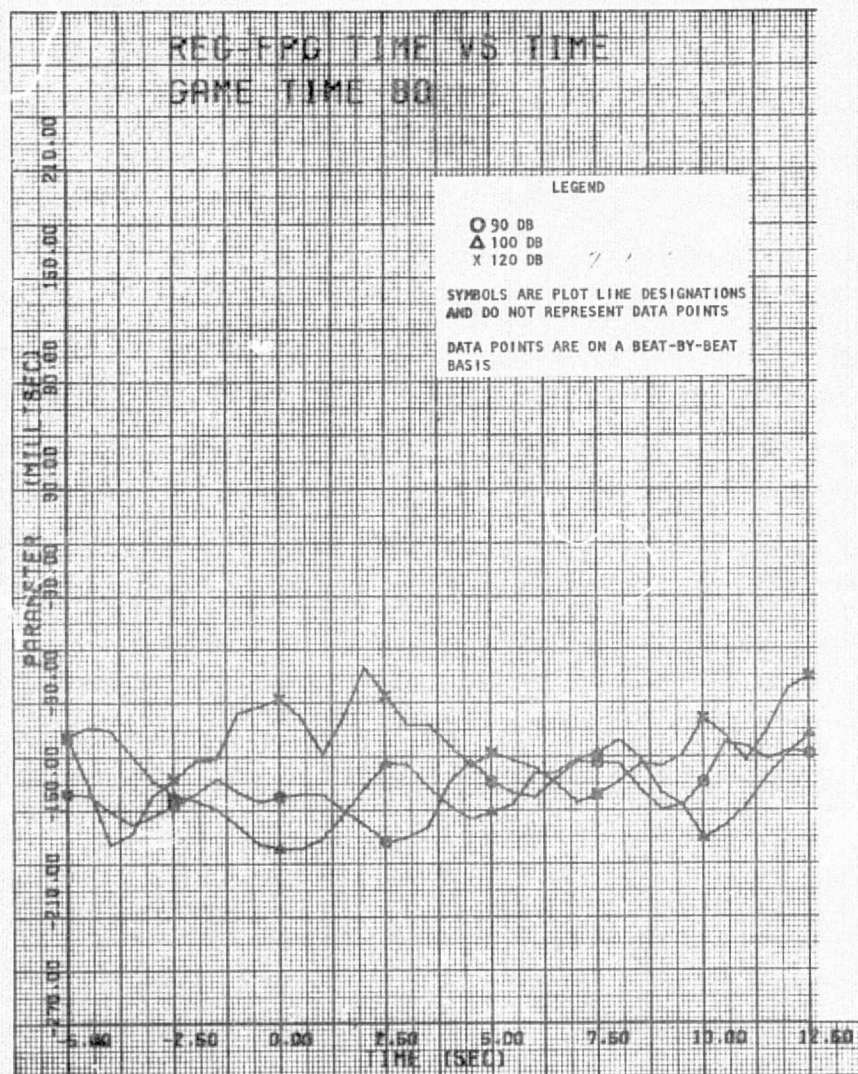Task Duration, VM Task 3)--Response 2
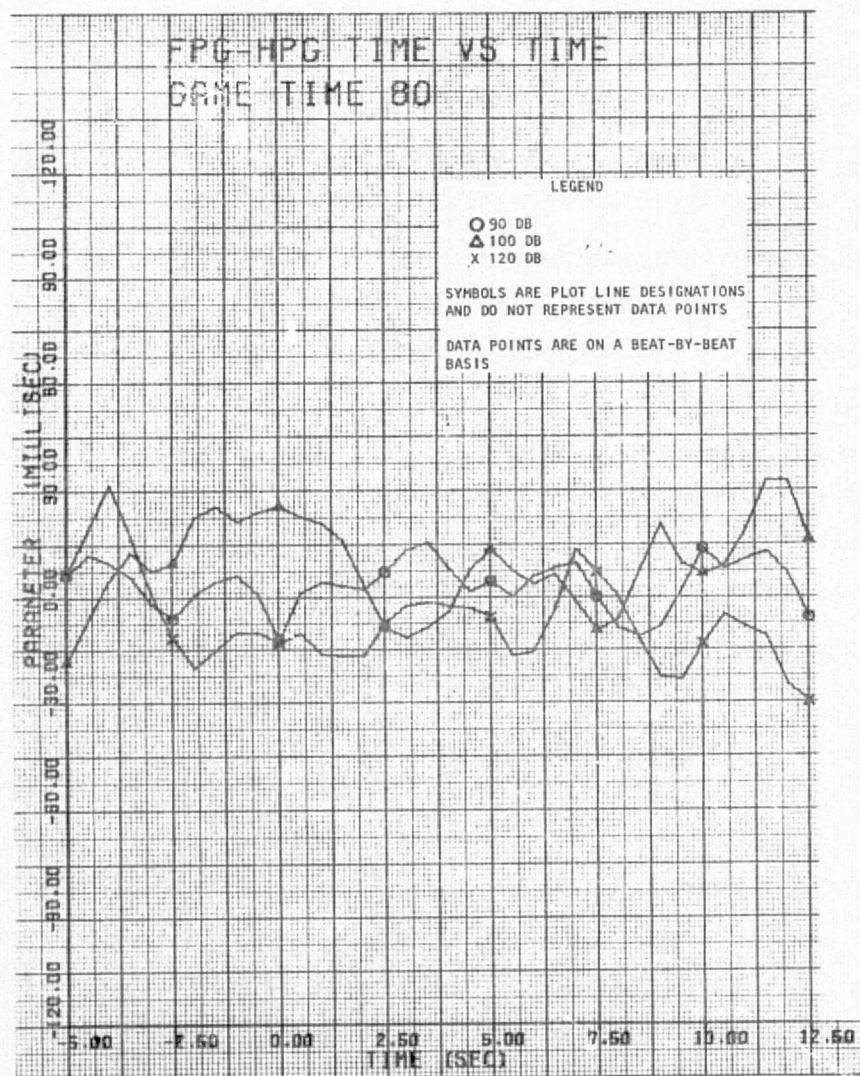
Figure 7-150. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--80-Sec Game Time
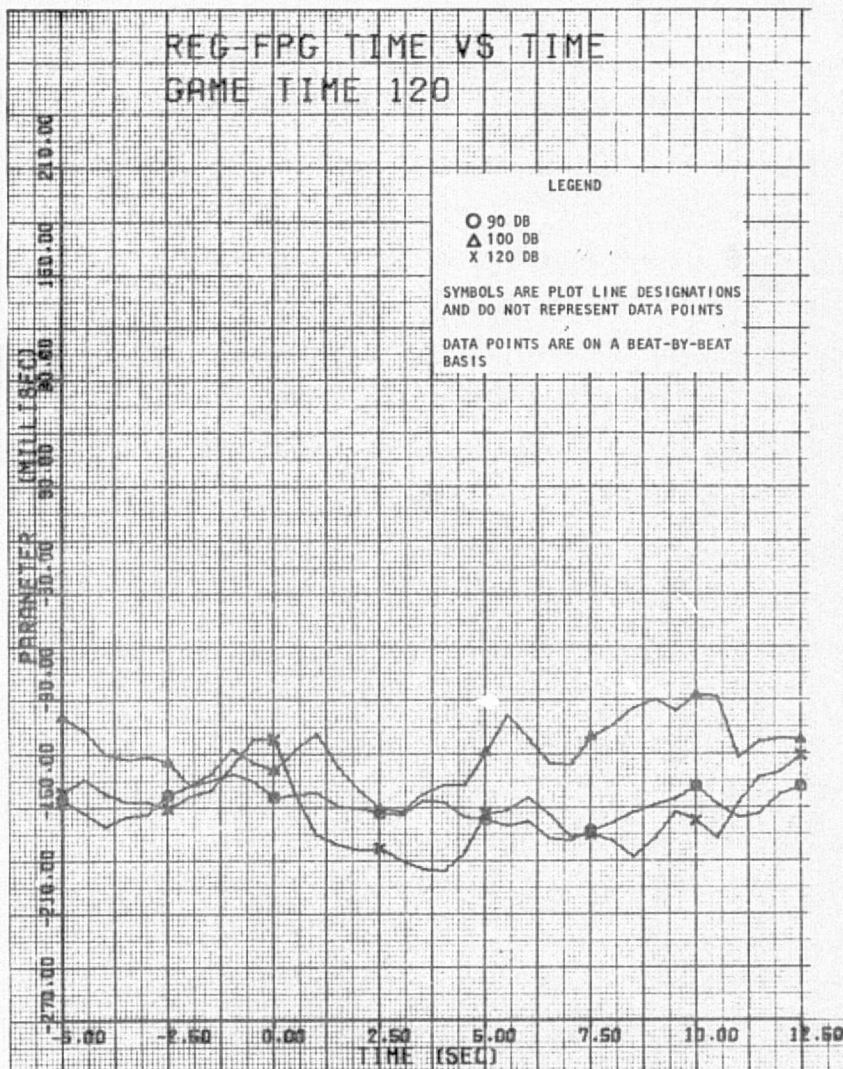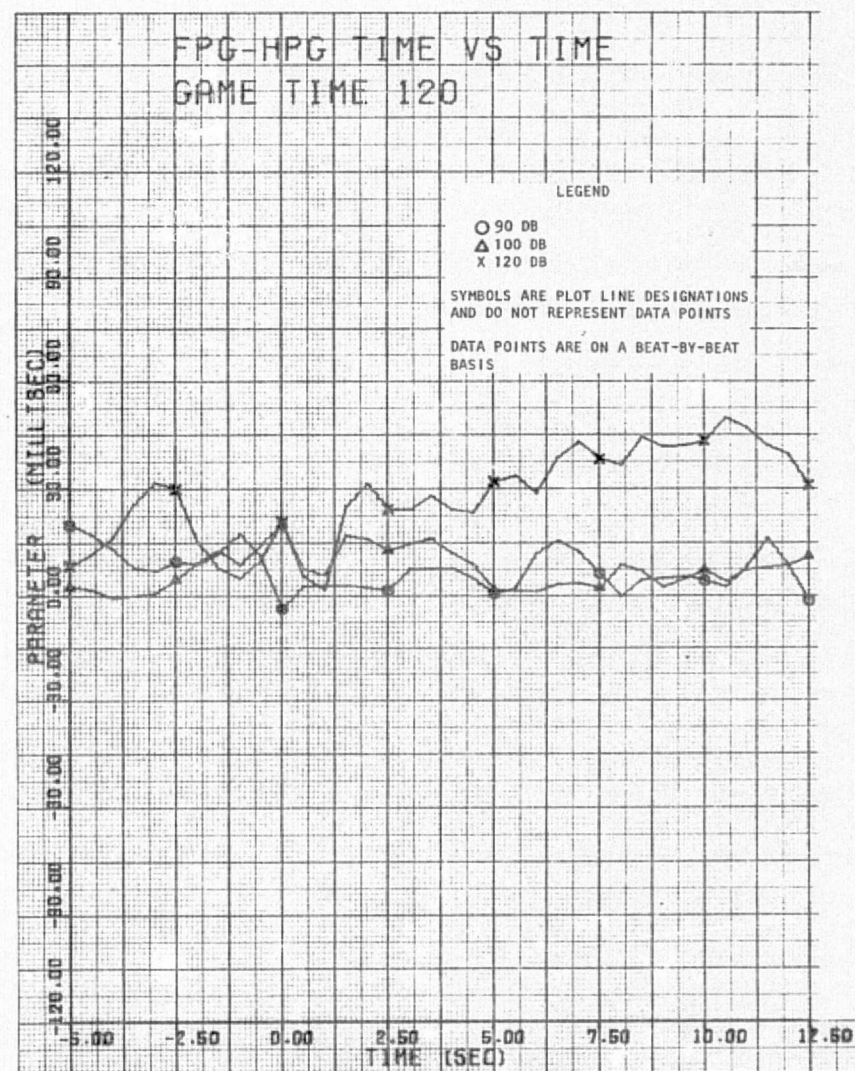


Figure 7-151. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--120-Sec Game Time
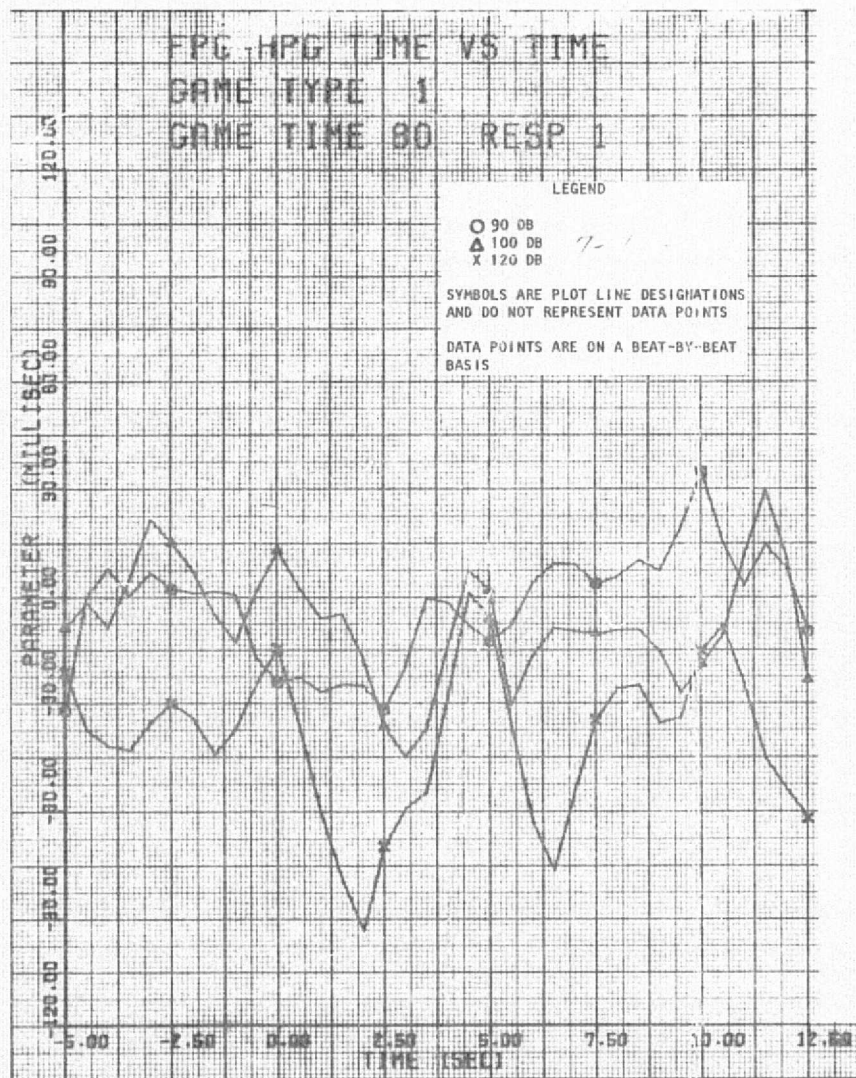
Figure 7-152. FPG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1,
80-Sec Game Time, Response 1
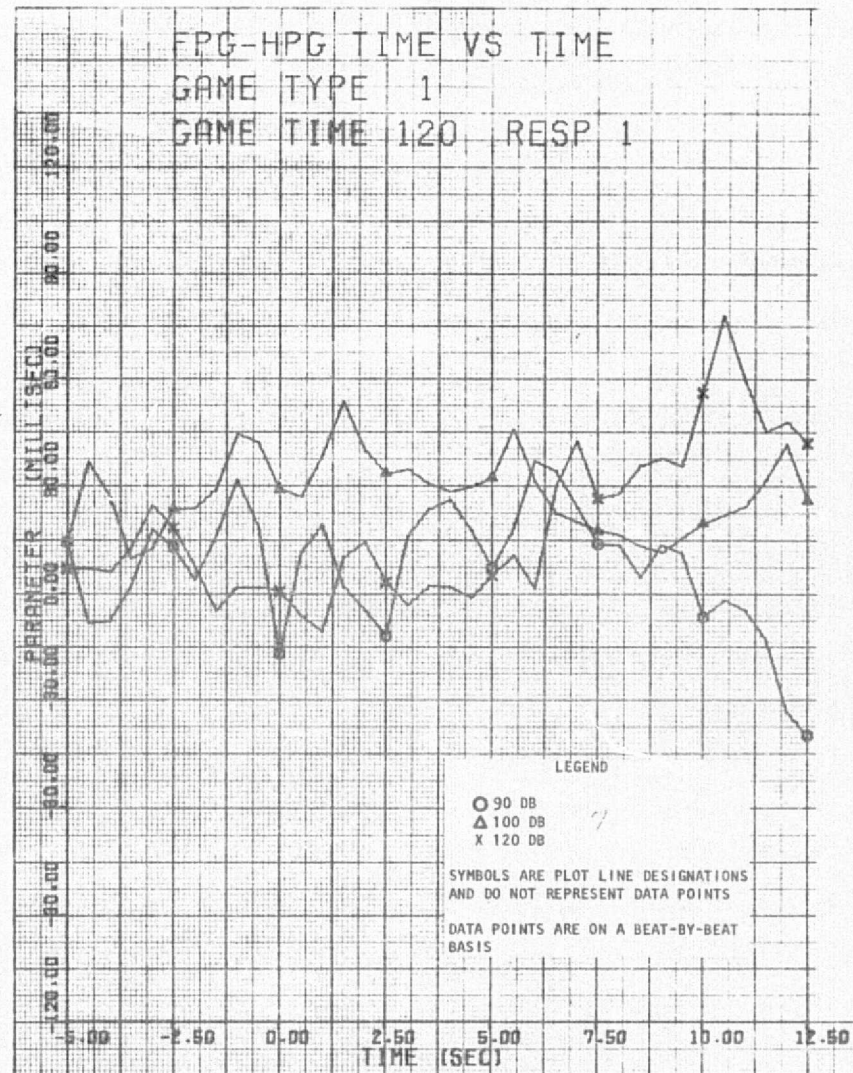


Figure 7-153. FPG-HPG Time Internal for Test Day 3,
Conditions 5 and 6 (Less 110 db, 100-Sec
Task Duration, VM Task 3)--Game Type 1,
120-Sec Game Time, Response 1
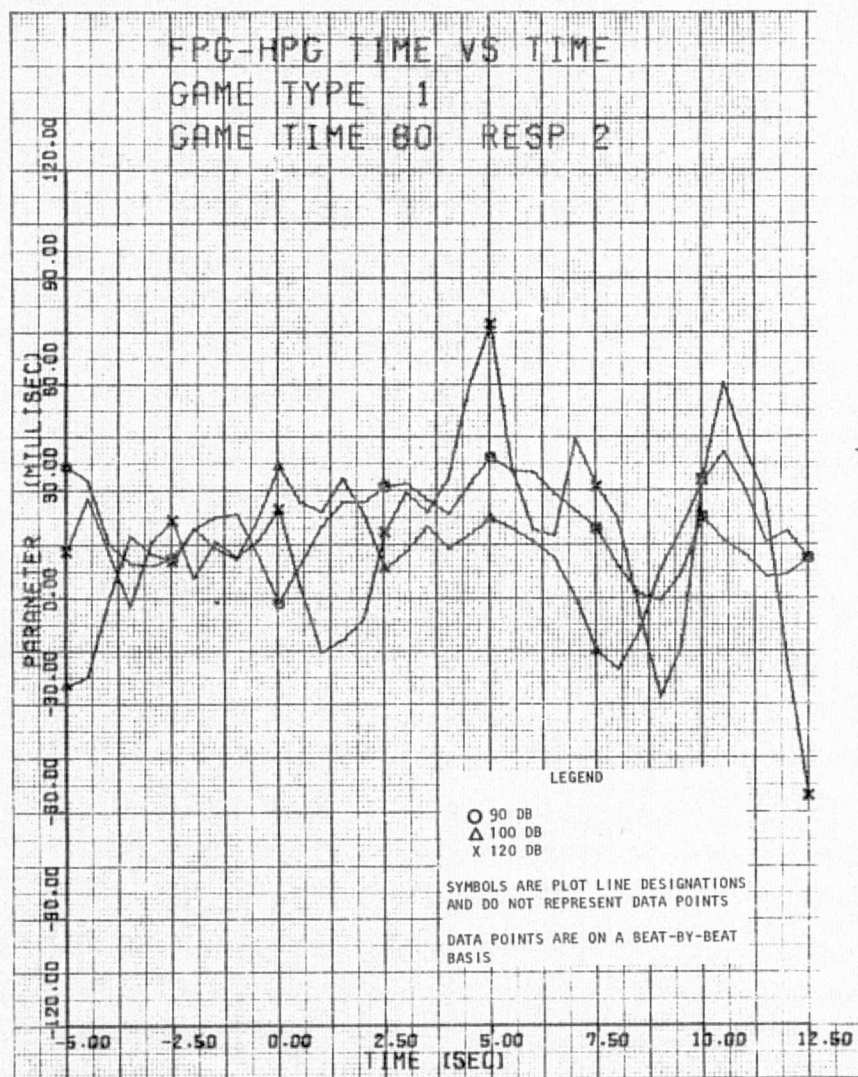
Figure 7-154. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 80-Sec Game Time, Response 2
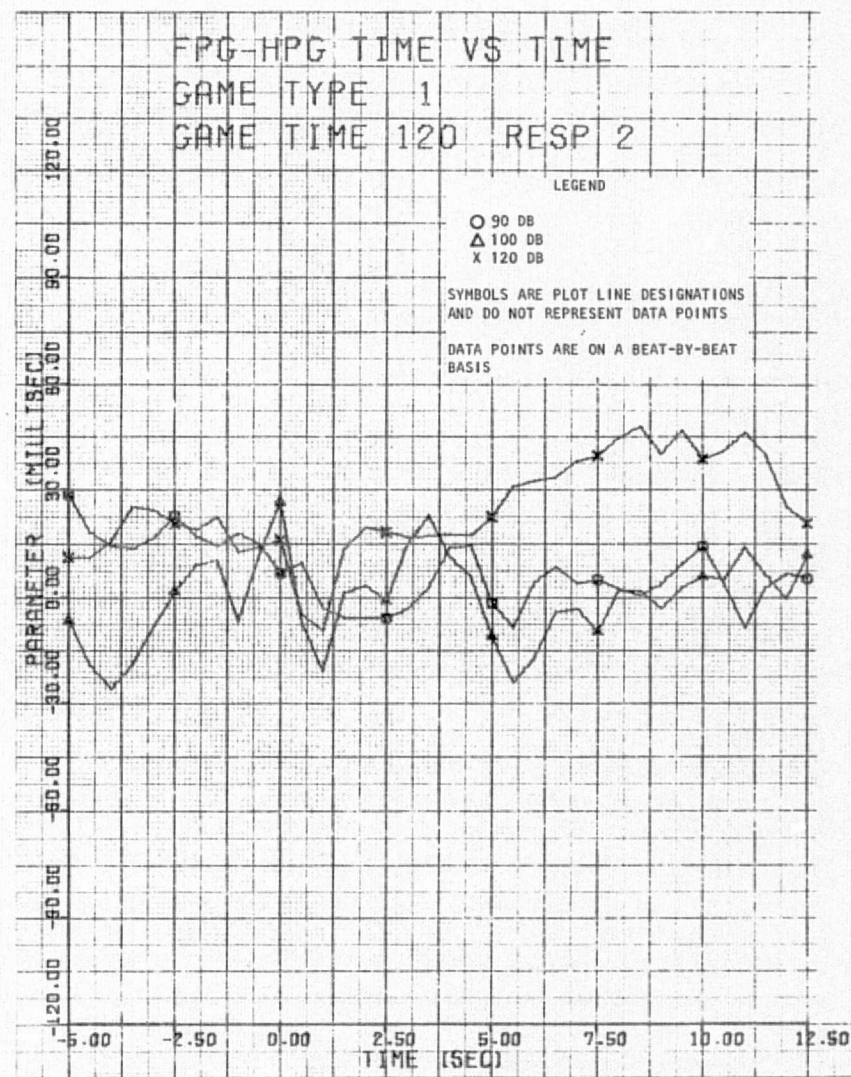
Figure 7-155. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 1, 120-Sec Game Time, Response 2
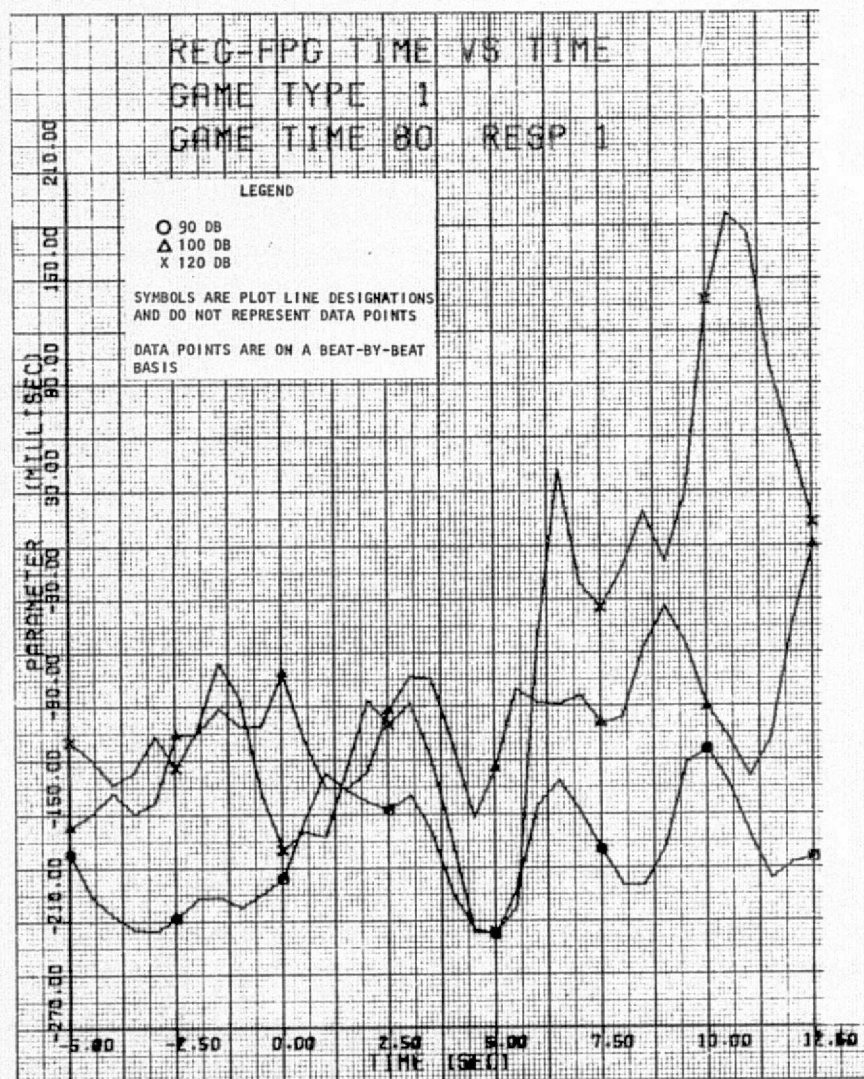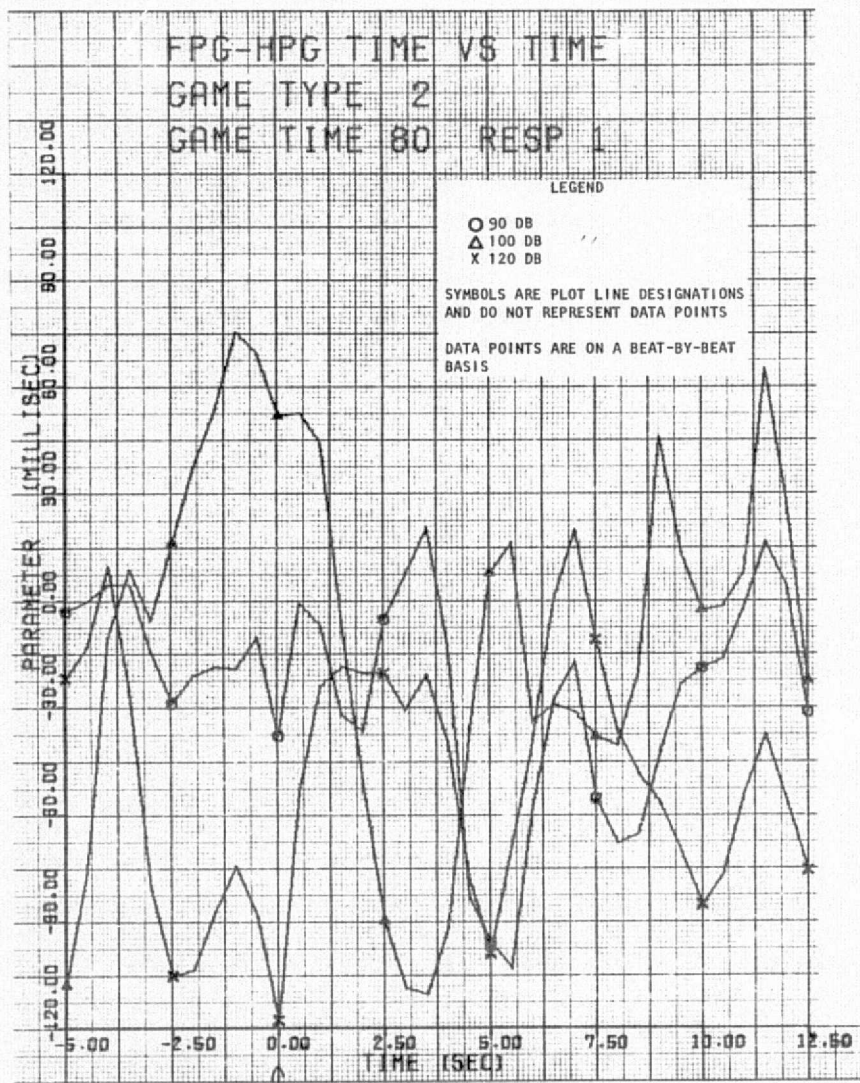
Figure 7-156. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 1
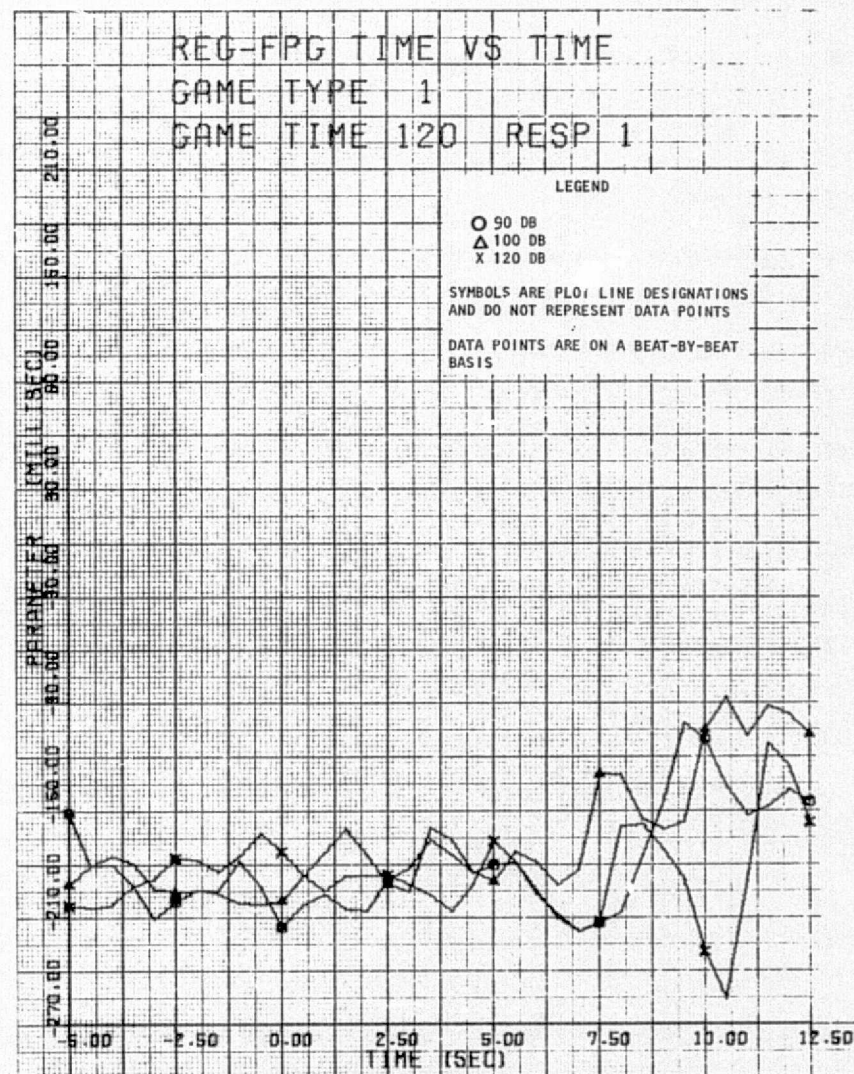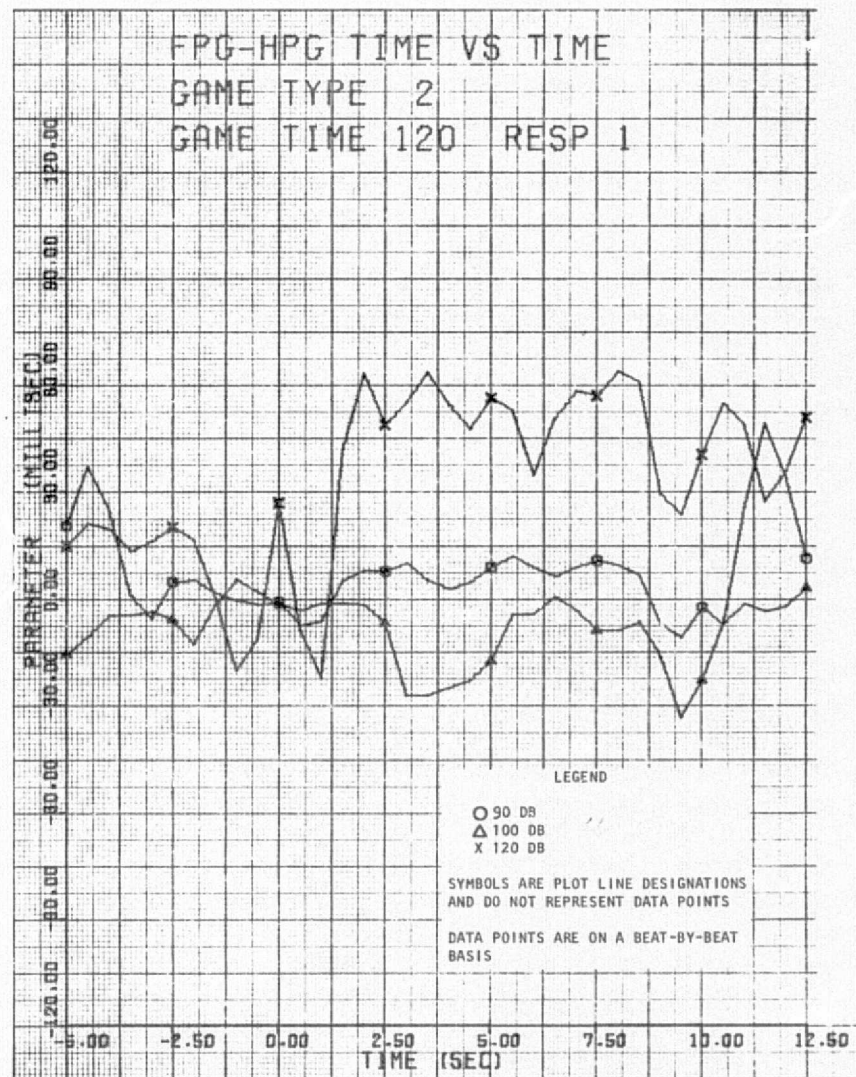


Figure 7-157. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 1
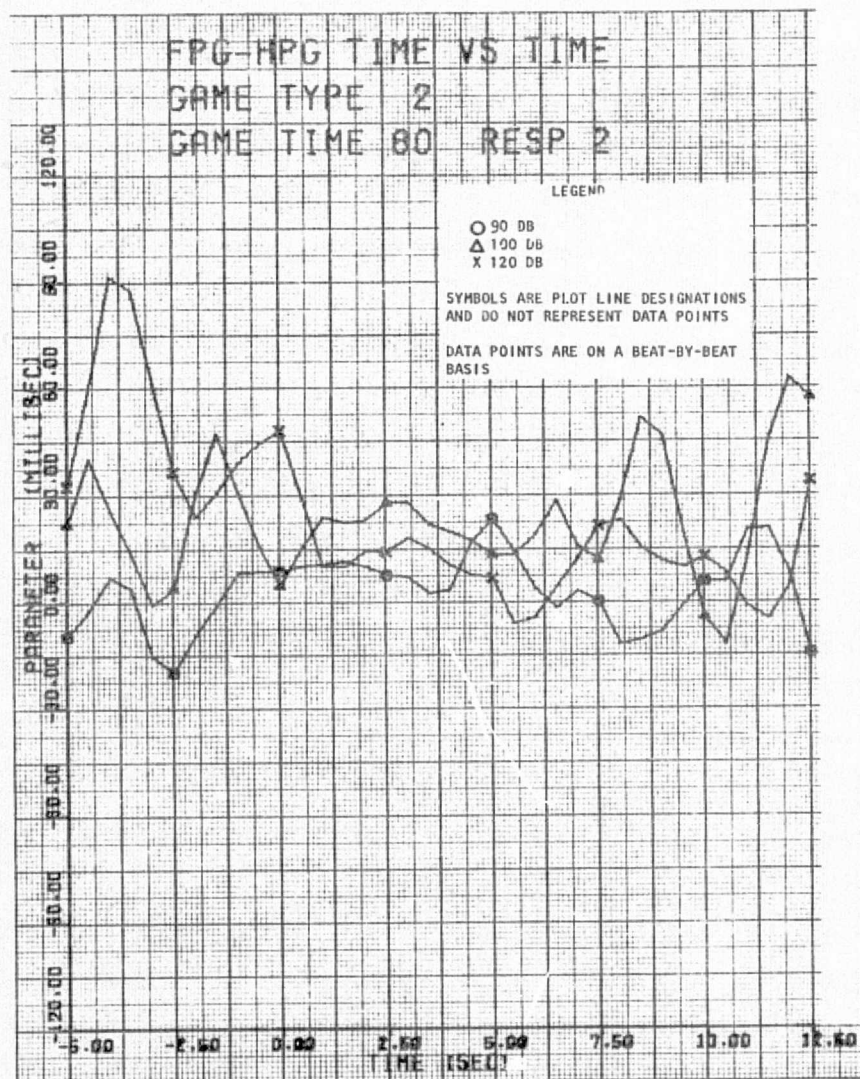
Figure 7-158. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 80-Sec Game Time, Response 2
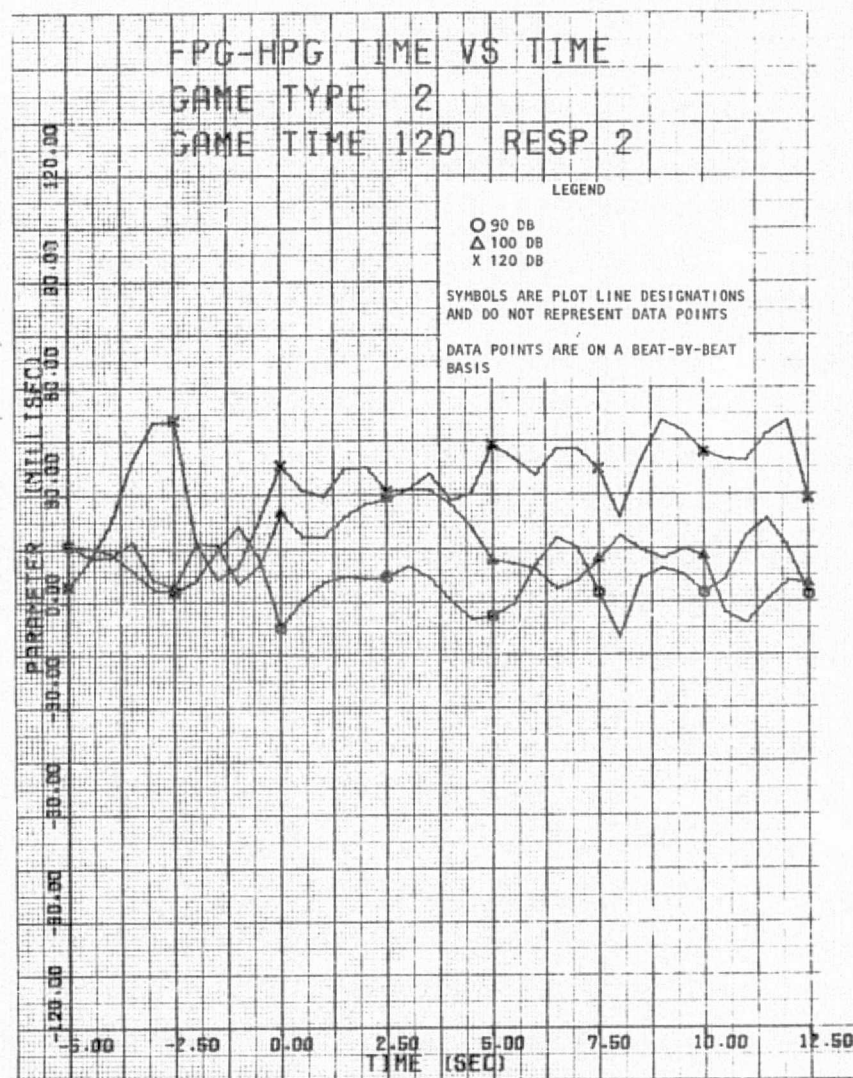
Figure 7-159. FPG-HPG Time Internal for Test Day 3, Conditions 5 and 6 (Less 110 db, 100-Sec Task Duration, VM Task 3)--Game Type 2, 120-Sec Game Time, Response 2

# SECTION VIII

## CONCLUSIONS AND RECOMMENDATIONS

### CONCLUSIONS

The following conclusions have resulted from evaluation of the work described in this report:

(a) It can be concluded from this experiment that performance and physiological dependent variables can be utilized to evaluate situational induced stress on task performance.

(b) All of the following independent situational variables have simple and interaction effects on performance and physiological dependent variables: auditory probe stimulus intensity, inclusion/exclusion of a VM task, VM task difficulty (type of VM task), inclusion/exclusion of a reaction time task, and training.

(c) Physiological and performance dependent variables track each other in response to independent variable contingencies.

(d) Reaction time is increased by about 37 percent by the inclusion of the VM task as a forcing function.

(e) Reaction time is differentially affected by VM task difficulty.

(f) Task type, task duration, and auditory probe stimulus intensity interact to produce uniquely low reaction times within the VM task situations.

(g) Each independent variable (task duration, auditory probe intensity, training, inclusion of the VM task, and VM task duration) has statistically significant effects on the reaction time.

(h) Reaction time can be utilized as a DV for the purposes of evaluating the behavioral impositions of tasks, stimulus intensity, and time constraints.

(i) VM task performance is not influenced by the inclusion of the reaction time task, whereas RT is dramatically affected by inclusion of the task and task difficulty. This suggests that an auditory probe stimulus with a reaction time response could be employed as a psychophysiological test probe under some conditions without interfering with task performance.

(j) The various test parameters of different VM task types, VM task durations, and training have significant effects on task performance.

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(j) The various test parameters of different VM task types, VM task durations, and training have significant effects on task performance.

(k) Lower average heart rates accompany the more difficult tasks and short task duration.

(l) Higher heart rates were found to correspond to the quicker reaction time performance.

(m) Reaction time task inclusion results in an increase in heart rate variability, a decrease in FPG amplitude, an increase in FPG amplitude variability, more variability in the ECG-FPG elapsed time, increased variability in HPG amplitude, and lower REG pulse amplitude.

(n) FPG amplitude is the lowest when heart rate is the highest and RT performance is at its best.

(o) REG pulse amplitude decreases with increasing task difficulty.

(p) HPG and REG responses essentially mirror one another, with REG always leading HPG.

(q) The most interesting "temporal difference" parameter is the change in temporal relationship between HPG and FPG pulse arrival times. Under the less demanding task conditions, the HPG pulse occurs prior to FPG pulse. As the task demands of the situation increase, FPG shifts from lag to lead. A similar change occurs in the variability of the parameter becoming more variable with increasing task difficulty.

These conclusions give strong credence to the contention, established in Section 1, that physiological and performance indicators can be utilized as objective means for psychological assessment. However, much work needs to be done to carry the work through to the point of application in operational spaceflight. Recommendations for the subsequent phases of development follow.

RECOMMENDATIONS

It is recommended that the following be accomplished:

(a) This experimental paradigm should be carried forward into four situations:

(1) Emotionally arousing test situations

(2) Social and perceptual isolation situations

(3) Spaceflight simulations

(4) Earthbound monitoring of ongoing situations (e.g., piloting on transcontinental flights)

(b) The remainder of the unanalyzed physiological data collected on this program needs to be reduced to clarify:

   (1) The order effects of the independent variables

   (2) The extent of physiological response habituation between the first and third day of testing

   (3) The reliability of the physiological dependent variables.

# APPENDIX A

## INSTRUMENTATION MANUAL
## PSYCHOLOGICAL ASSESSMENT SIGNAL CONDITIONER

.

# APPENDIX A

## INSTRUMENTATION MANUAL
## PSYCHOLOGICAL ASSESSMENT SIGNAL CONDITIONER

### SYSTEM SPECIFICATION SHEET
### ECG Amplifier*

## INPUT

Range - Amplitude          0.01 to 20.0 mv

      - Frequency response          0.1 to 100 Hz

      - Sensitivity          Fixed at 2 mv/v

Impedance

    Differential          10 megohm          Single-ended          N/A

    Common mode          1 megohm

    Common mode rejection - dc          70 db

                          - ac          60 db to 1 kHz

    Max. common mode input          ±10 vdc or 20 v p-p ac

Waveform - any

    Crest factor          N/A

    Form factor          N/A

## OUTPUT

Range - Amplitude          0 to ±10 vdc

      - Frequency response          0.1 to 100 Hz

      - System gain          X 500

Impedance

    Differential          N/A          Single-Ended          50 ohm

    Common mode          N/A

Waveform

    Crest factor          N/A

    Form factor          N/A

---

*See Dwg. LSK 36171, Appendix B

READOUT     NONE

    System Errors - Linearity N/A          Precision N/A

               Threshold N/A          Resolution    0.05 mv

               Hysteresis N/A

               Drift - with time

                     with temperature      N/A

                     with supply           N/A

               Noise - Ripple                  l mv p-p (RTO)

    Power requirements          ±15 vdc at 20 ma

    Environmental specifications

               Temperature        $70^{o}$C max.

               Humidity           90 percent max.

               Acceleration       Normal handling shock

    Mechanical specifications

               Configuration      PC Card

               Size               3-3/4 by 6-1/2 by 1 in.

               Volume           24.4 cu in.

               Weight           6 oz

## SYSTEM SPECIFICATION SHEET
### REG Amplifier*

INPUT

       Range – Amplitude          0 to 10 vdc or ac pk
             – Frequency response          dc to 1 kHz
             – Sensitivity
       Impedance
              Differential          20 k              Single-ended    20 k
              Common mode          10 k
              Common mode rejection – dc          60 db
                                    – ac          60 db to 1 kHz
              Max. common mode input    ±10 vdc or ac pk
       Waveform – any
              Crest factor          N/A
              Form factor          N/A

OUTPUT

       Range – Amplitude          0 to ±10 vdc or 20 v p-p ac
             – Frequency response          dc to 1 kHz
             – System gain          Unity (x1)
       Impedance
              Differential          N/A          Single-ended <10 ohm
              Common mode          N/A
       Waveform – any
              Crest factor          N/A
              Form factor          N/A

READOUT       NONE

       System errors – Linearity          N/A       Precision          N/A
                       Threshold          0.5 mv    Resolution          0.5 mv
                       Hysteresis          N/A

---

*See Dwg. LSK 36175, Appendix B

A-3

```
        Drift - with time           N/A
               with temperature          N/A
               with supply              N/A
        Noise- Ripple                            0.5 mv rms (RTO)
Power requirements              ±15 vdc at 30 ma
Environmental specifications
        Temperature            70°C max.
        Humidity               90 percent ± max.
        Acceleration                     Shock Normal handling
Mechanical specifications
        Configuration          PC Card
        Size                   3-3/4 by 6-1/2 by 1/2 in.
        Volume                 12 cu in.
        Weight                 6 oz
```

# SYSTEM SPECIFICATION SHEET
## FPG and HPG Amplifier*

## INPUT

Range – Amplitude     0 to ±150 mv dc or pk ac

    – Frequency response     dc to 100 Hz at -3 db

    – Sensitivity     16.6 mv/v

Impedance

    Differential    100 k       Single-ended    50 k

    Common mode    50 k

    Common mode rejection – dc    60 db

                      – ac    60 db to 1 kHz

    Max. common mode input    ±10 vdc or 20 v p-p ac

Waveform – any

    Crest factor    N/A

    Form factor    N/A

## OUTPUT

Range – Amplitude     0 to ±10 vdc or 20 v p-p ac

    – Frequency response     dc to 100 Hz

    – System gain     X 10 to X 60

Impedance

    Differential    N/A       Single-ended <10 ohm

    Common mode    N/A

Waveform – any

    Crest factor    N/A

    Form factor    N/A

## READOUT     NONE

System Errors – Linearity    N/A     Precision    N/A

               Threshold    0.5 mv    Resolution    0.5 mv

               Hysteresis    N/A

---

*See Dwgs. LSK 36179 and 36180, Appendix B

```
          Drift - with time          N/A
                    with temperature          N/A
                    with supply               N/A
          Noise - Ripple                             I mv p-p (RTO)
Power requirements                  ±15 vdc at 40 ma
Environmental specifications
          Temperature               70°C max.
          Humidity                  90 percent max.
          Acceleration                          Shock    Normal handling
Mechanical specifications
          Configuration             PC Card
          Size                      3-3/4 by 6-1/2 by 1/2 in.
          Volume                    12 cu in.
          Weight                    6 oz
```

# SYSTEM SPECIFICATION SHEET
## Audio Simulator*

### INPUT

Range - Amplitude       7 binary bit percent $(2^7 = 128:1$ range)

    - Frequency response    1 kHz max. program rate

    - Sensitivity    N/A

Impedance

    Differential    N/A        Single-ended    TTL compatible

    Common mode    N/A

    Common mode rejection- dc    N/A

            - ac    N/A

    Max. common mode input    N/A

Waveform - square

    Crest factor    N/A

    Form factor    TTL compatible

### OUTPUT

Range - Amplitude    60 to 120 db sound level

    - Frequency response    1 to 10 kHz tone

    - System gain    Variable output level from 40 to 70 db

Impedance

    Differential    N/A        Single-ended    < 10 ohm

    Common mode    N/A

Waveform - Sine

    Crest factor    N/A

    Form factor    N/A

### READOUT

System errors - Linearity    0.5 percent FS    Precision    N/A

        Threshold    1.2 percent FS    Resolution    1.2 percent FS

        Hysteresis    0.1 percent FS

---

*See Dwgs. LSK 36179 and 36180, Appendix B

```
            Drift - with time          0.01 percent/hr
                    with temperature          0.1 percent/$^o$C
                    with supply               0.2 percent/V
            Noise - Ripple                    1 mv rms
Power requirements                    ± 15 vdc at 80 ma
Environmental specifications
            Temperature               70$^o$C max.
            Humidity                  90 percent max.
            Acceleration                    Shock      Normal handling
Mechanical specifications
            Configuration             2 ea - PC Cards
            Size                      3-3/4 by 6-1/2 by 1 in., each card
            Volume                    48 cu in.
            Weight                    14 oz total
```

## DISCUSSION OF SYSTEM DESIGN

The physiological assessment (PA) signal conditioner provides interfacing between a test subject and a digital computer. The subject's physiological reactions are picked up via sensors, conditioned by the signal conditioner unit, and recorded and analyzed by the digital computer to determine the subject's psychological condition. A block diagram of the signal conditioning system is shown in Figure A-1 (also see Figure 5-1, the instrumentation block diagram). Because of the complexity of the system, the design discussion will be handled separately for each of the following subsystems:

  Electrocardiograph (ECG)

  Rheoencephalograph (REG)

  Plethysmograph (FPG and HPG)

  Audio response simulator

### Electrocardiograph

The electrocardiograph (ECG) uses three sensors to pick up the electrical activity of the heart: (1) a positive sensor, (2) a negative sensor, and (3) a reference sensor. The reference sensor is placed centrally on the subject's sternum (see Figure A-4a). The positive and negative sensors are placed on opposite sides of the subject's sternum, as far apart as possible while still over bone. The positive sensor is placed on top, the negative below.

The electrical activity picked up by ECG sensors indicates heart rate, blood pressure, and heart volume changes. On this program, we are only interested in the heart rate signal. A typical heart rate signal waveform is shown in Figure A-2a. The voltage at the R point has a level of 1 to 2 mv, depending on the type of sensors used and their placement on the subject. The period of the heart rate signal ranges from 1-1/2 to 1/2 sec, which corresponds to a heart rate of 40 beats/min to 120 beats/min.

The sensors used are silver/silver floating biodes, which are held in place with double-sided tape, and make electrical contact to the skin through a liquid medium (biogel) produced especially for this purpose. See Figure A-2b for sensor details.

The differential voltage level at the output of the ECG sensors ranges from 0.1 to 2 mv peak, while the common-mode voltages range from 10 to 100 mv peak. For this reason, a differential amplifier with high common-mode rejection (CMR) is required for this subsystem. Referring to Dwg. LSK 36171, Appendix B, it can be seen that the ECG amplifier consists of three operational amplifier (op amp) units. The input stage consists of two op amps connected in a high CMR, common feedback configuration. This circuit uses the op amps as noninverting stages. In this mode, the input impedance at the positive input terminal is greater than 10 megohms. The feedback for this first stage uses a common resistor (R3) to determine the stage gain. This method helps match the gains of the two input op amps, which provides maximum CMR. The third op amp is used

Figure A-1. System Block Diagram (Sheet 1 of 2)
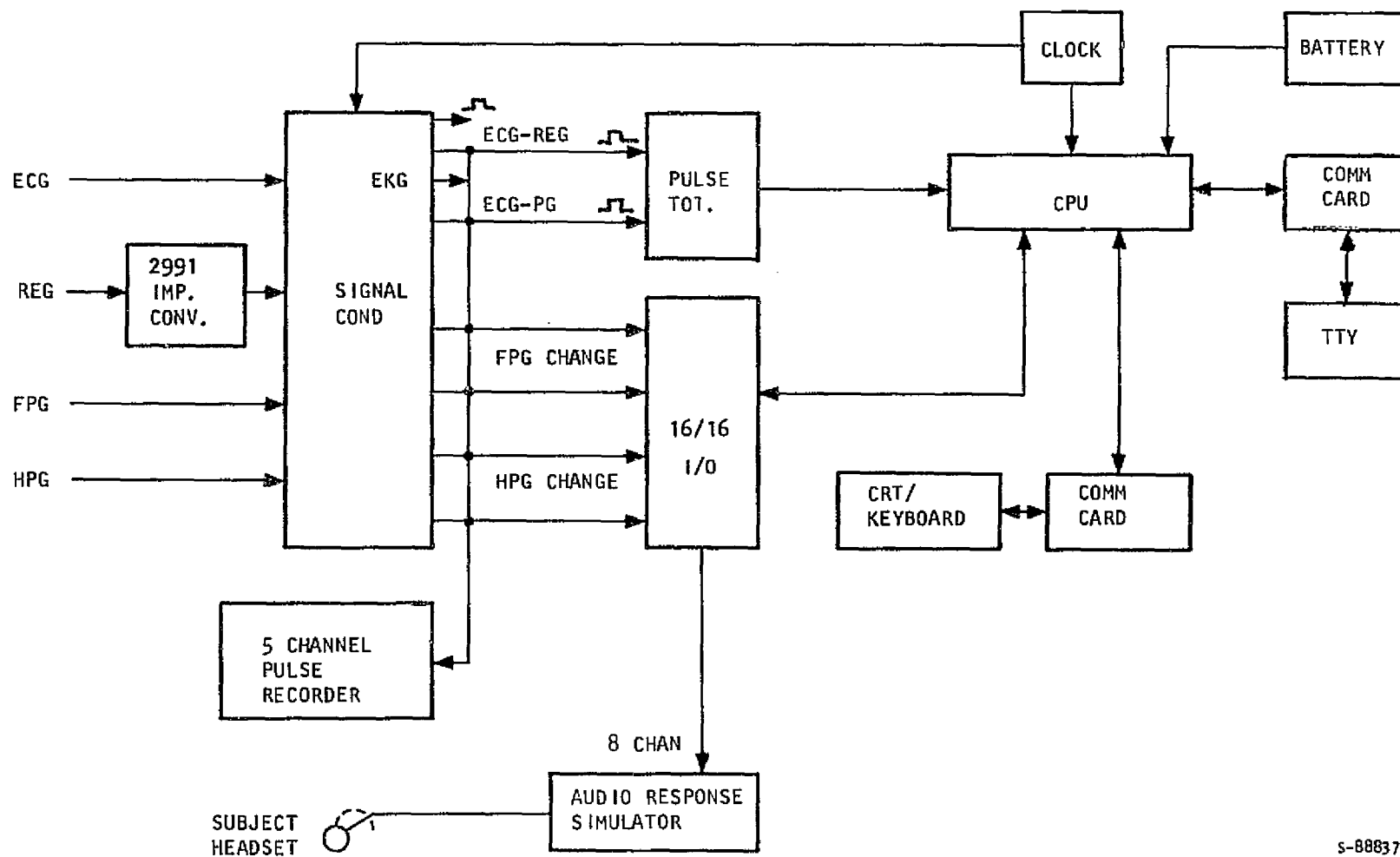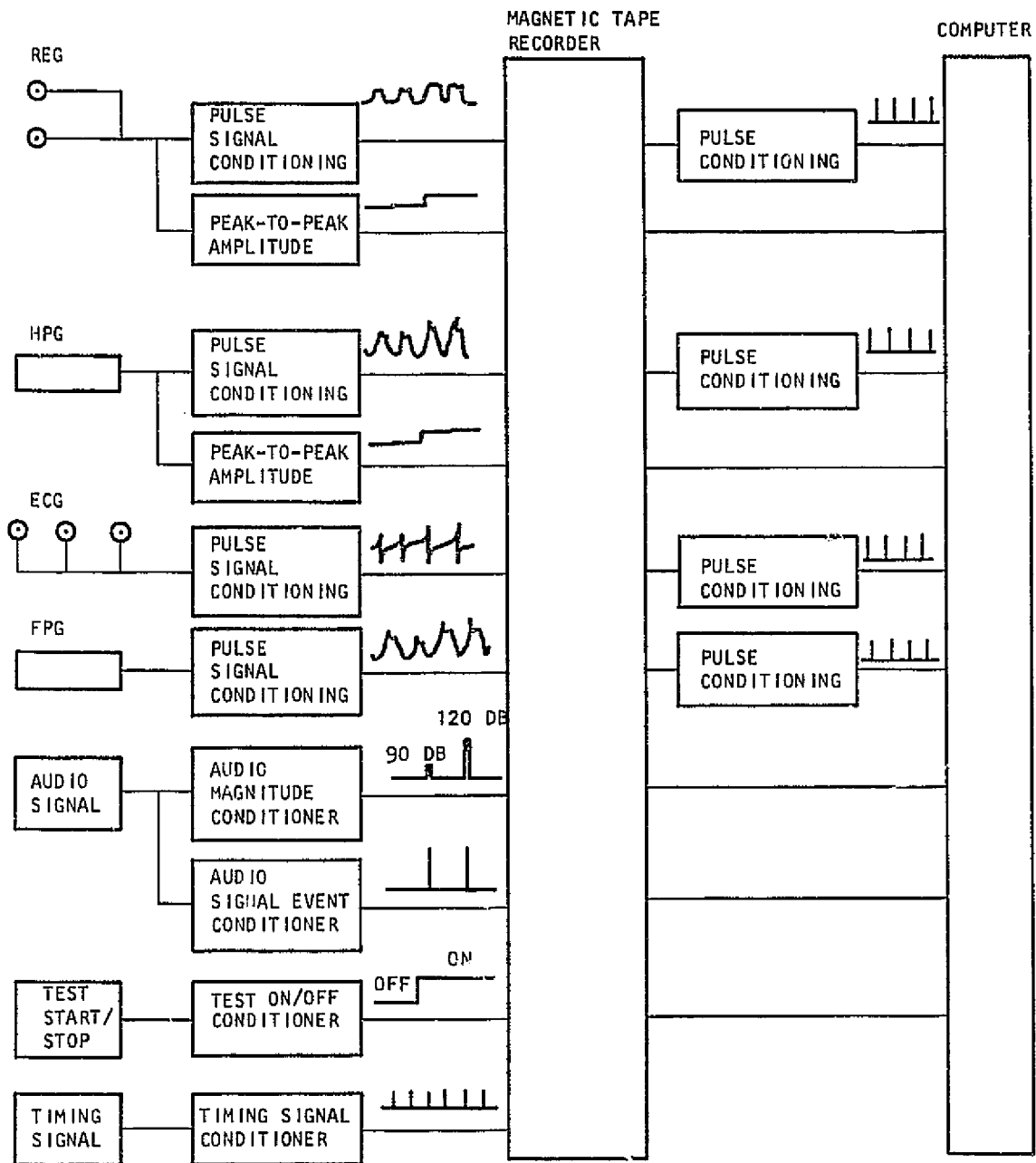
s-88837

Figure A-1. System Block Diagram (Sheet 2 of 2)

(a) ECG WAVE FORM



(b) SILVER/SILVER BIODE



SKIN

SILVER DISK

SILVER ELECTRODE
PASTE

CONTACT
MEDIUM
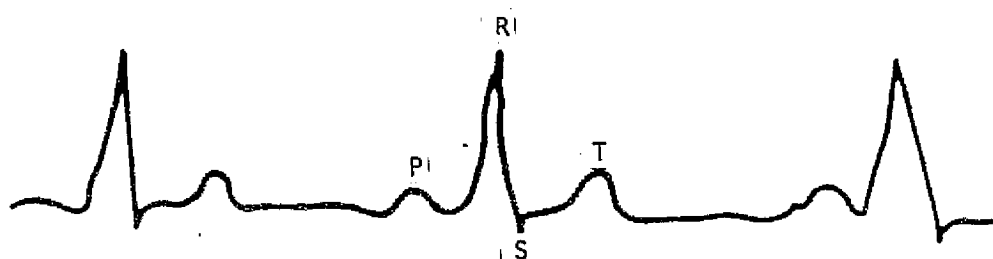
CABLE
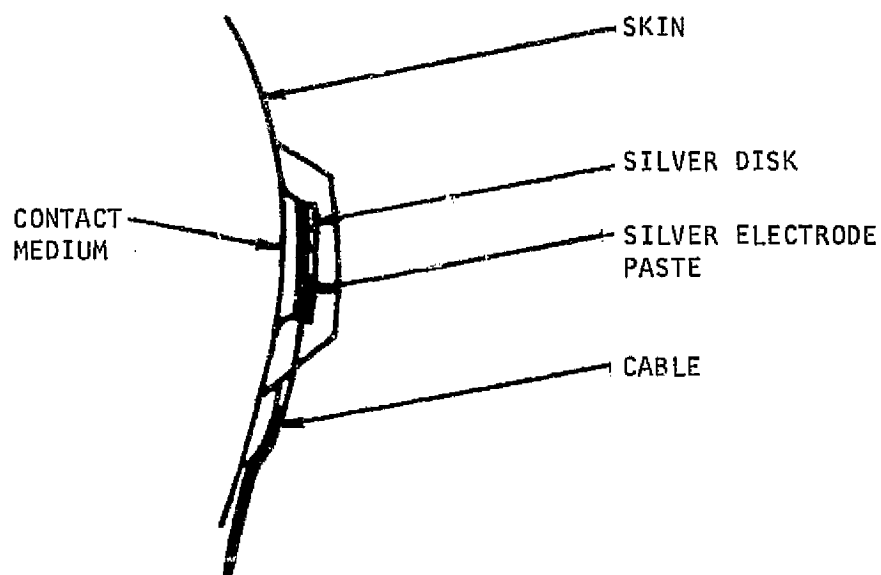
S-88998

Figure A-2. Typical Heart Rate Signal Waveform

(a)  REG WAVE FORM



(b)  PG WAVE FORM



S-88996

Figure A-3.  Signal Waveforms  (REG and PG)

both as a differential to single-ended converter stage, and a gain stage. This stage is capacitor-coupled to the first stage to help eliminate baseline (zero) shift due to poor sensor/subject connections. The output of this amplifier is routed to an analog output terminal, and to the PG-ECG-REG level comparator board. This comparator board accepts the ECG analog signal, compares it to an adjustable level, and then uses the square wave obtained from the level comparator to trigger an integrated flip-flop. This flip-flop opens a gate allowing clock pulses coming from the digital computer to flow into a pulse totalizer unit. The flip-flop is reset by a signal generated by the REG/PG amplifiers, thus stopping the flow of clock pulses. The number of pulses that have been accumulated within the pulse totalizer unit is proportional to the time difference between an ECG pulse and a REG/PG pulse. This time difference data is used by the digital computer to help determine the psychological state of the subject.

## Rheoencephalograph

The rheoencephalogram (REG) is a measure of the fluctuation in cerebral tissue impedance due to pulsations of blood flow. The sensors used are 1-1/2-in. square sponges soaked in saline solution, which are placed on each temple. These biodes are held in place with an elastic headband. In use, the patient constitutes the unknown arm of a balanced Wheatstone bridge that is excited by a 10 to 50 kHz sine-wave signal. The ac output of the bridge is detected and amplified to yield a 0 to 2 v-peak output signal for a 0 to 5 percent change in cerebral impedance. The REG signal has the waveform shown in Figure A-3a. The period of this signal ranges from 1/2 sec down to 1/3 sec.

The REG signal is preconditioned by a commercial signal conditioning unit, a Biocom impedance converter (BK). The output of this unit is a 0- to ±2-v signal. From the BK, the signal is routed to the REG amplifier card (Dwg. LSK 36175, Appendix B).

In this circuit, the first stage (Z1) is connected as a unity gain differential amplifier. This is done to avoid ground loops that may occur between the PA signal conditioner and BK unit. The output of this first stage is applied to a level comparator stage, (Z2). This stage compares the REG signal to an adjustable dc level. The square wave that is produced is routed to the REG-ECG-RG comparator card, where it is used to trigger an integrated flip-flop. This flip-flop, which is set by the ECG pulse and reset by the REG pulse, gates a clock signal that is used to calculate the time difference between the ECG and REG pulses.

## Finger Plethysmograph and Head Plethysomograph

The plethysmograph sensors (FPG and HPG) are used to measure blood volume change at a specific point on the body. Two sensors are employed for this test: (1) a finger sensor, and (2) a head sensor. Both of these sensors operate by measuring the amount of a specific wavelength of light (7350A), which is absorbed by the monitored organ. The light is generated by a small light source and it is conducted by the skin of the subject to a nearby photocell. The photocell produces a resistance change proportional to the amount of light

falling on it. The photocell is connected into a bridge circuit that translates
the resistance change into a voltage signal. (See Dwg. LSK 36174, Appendix B,
for more details on this bridge circuit; see Figure A-3b for details on the
PG signal waveform). The voltage signals are routed to the PG and EPG amplifier
cards LSK 36172 and LSK 36173. These cards consist of a differential input
stage with a gain of 20, a second ac-coupled stage with a variable gain of 1/2
to six, and a comparator stage that compares the analog signal level with an
adjustable dc level. The square wave produced by this comparator stage is used
to gate a flip-flop, which allows a series of clock pulses to pass into a pulse
totalizer unit. The total number of pulses counted at the end of a cycle is
proportional to the time between an ECG pulse and a PG pulse. This time
difference is used by the digital computer to help determine the subject's
psychological state.

Audio Response Simulator (See Dwg. LSK 36179, Appendix B)

Then the controlled level output from the multiplier is applied to the audio
driver card, LSK 36180, where it is amplified to the level necessary to drive a
set of stereo headphones. The final output sound level is program controllable
to the input of a digital-to-analog (D/A) converter. The output of this D/A
converter is a 0- to 10-vdc level. This signal is applied to the second stage,
which performs level shifting and scaling on the D/A signal. The output of the
second stage is then applied to the X input of a multiplier. The Y input of the
multiplier is fed from a sine wave oscillator located on PC card LSK 36180. The
multiplier is used in this case as a linear amplitude modulator, providing an
output level proportional to the digital binary number input to the D/A converter.

Then the controlled level output from the multiplier is applied to the audio
driver card, LSK 36180, where it is amplified to the level necessary to drive a
set of stereo headphones. The final output sound level is program controllable
from 60 to 120 db by the digital computer system. In this experiment, db levels
of 90, 100, 110, and 120 were used. The frequency of the tone is also manually
variable using a control on the front panel of the PA signal conditioner package.
The frequency range is 1 to 8 kHz. During testing, this control was set at
1656 Hz.

METHOD OF OPERATION

The step-by-step procedure for operating the PA signal conditioner is as
follows:

STEP 1

Plug the PA signal conditioner unit into a 115-v, 60-Hz power outlet.
Connect the cable from the PA unit to the digital computer. Connect the
ECG, PG, EPG, and BK cables to the PA unit inputs. Connect the REG sensors
to the inputs of the BK unit.

STEP 2

Turn on the signal conditioner unit and allow it to warm up for about 5 min.

STEP 3

Connect the ECG, REG, PG, and EPG sensors to the subject under test. Procedures for each sensor follow:

1. ECG Sensors

There are three silver/silver biodes used for the ECG input. The red (+) and black (-) biodes are applied to opposite sides of the subject's sternum, per Figure A-4a. The reference biode is applied to the center of the sternum. The procedure for applying each biode follows:

  a.   Using alcohol, clean the subject's skin in the area to which the biode will be applied. A slight abration of the skin using biobrade pads will remove the dry outer layer and thus lower the skin resistance.

  b.   Remove the double-sided adhesive washer (Biocom 1080B) from the wax-paper backing, leaving the top wax-paper washer in place.

  c.   Center the hole in the adhesive washer over the cavity in the biode and press the adhesive washer to the biode face.

  d.   Fill the biode cavity with biogel. Be sure that no voids or air bubbles are left in the gel during this process. The cavity should be slightly overfilled. The excess can be removed then using a stiff, straight edge (heavy paper, knife edge, etc.)

  e.   Remove the wax-paper washer and gently press the biode and washer in place.

NOTE:  Be sure to clean the silver/silver biodes with alcohol after each usage and use a new adhesive washer each time.

2. REG Sensors

The REG sensors consist of two 1-1/2-in. square sponge biodes, and are attached with an elastic headband. The placement on the subject is shown in Figure A-4b.

3. PG Sensors

The finger PG sensor simply is slipped over the subject's finger with the ball of the forefinger resting over the photocell output. See Figure A-5a for details. The head PG sensor is attached with a double-sided precut tape washer, the same type that is used for the ECG biodes.

a. ECG SENSOR ·PLACEMENT



POSITIVE (+)
ELECTRODE

REFERENCE (REF)
ELECTRODE

NEGATIVE(-)
ELECTRODE

CABLE
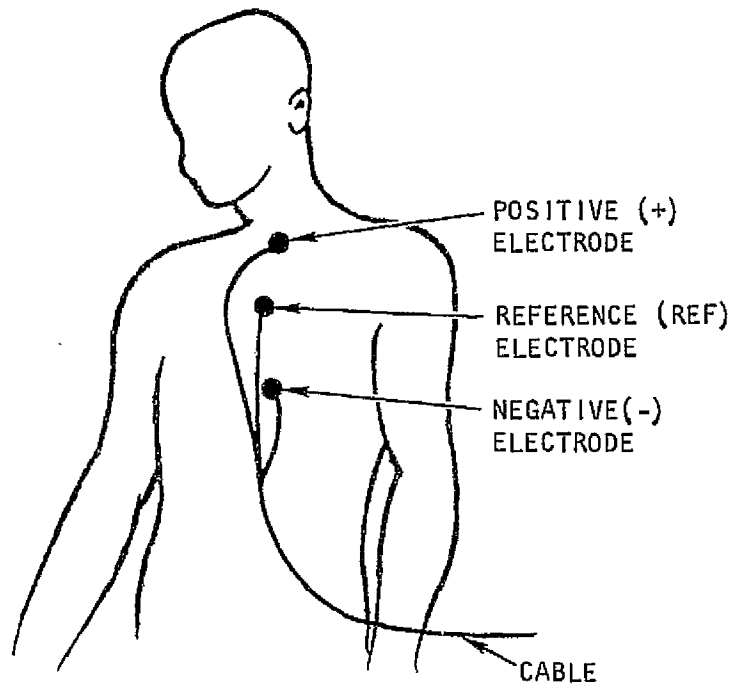
b. REG SENSOR PLACEMENT



SIDE  TOP  FRONT
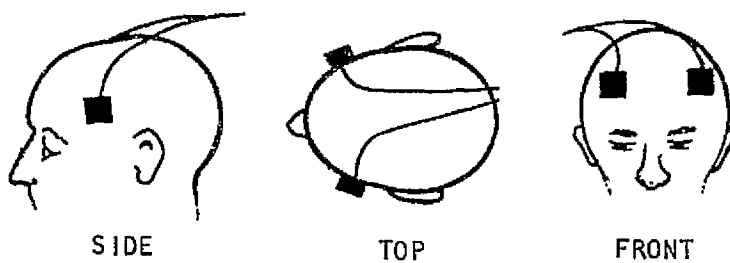
S-89021

Figure A-4. Sensor Placement (ECG and REG)

a. FPG SENSOR PLACEMENT



VELCRO BAND

LIGHT    PHOTOCELL

b. HPG SENSOR PLACEMENT



CABLE
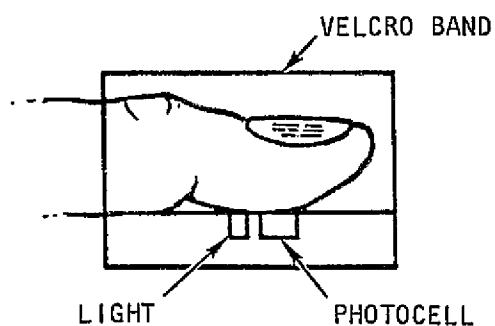
SENSOR
1/4 IN. ABOVE
RIGHT EYEBROW
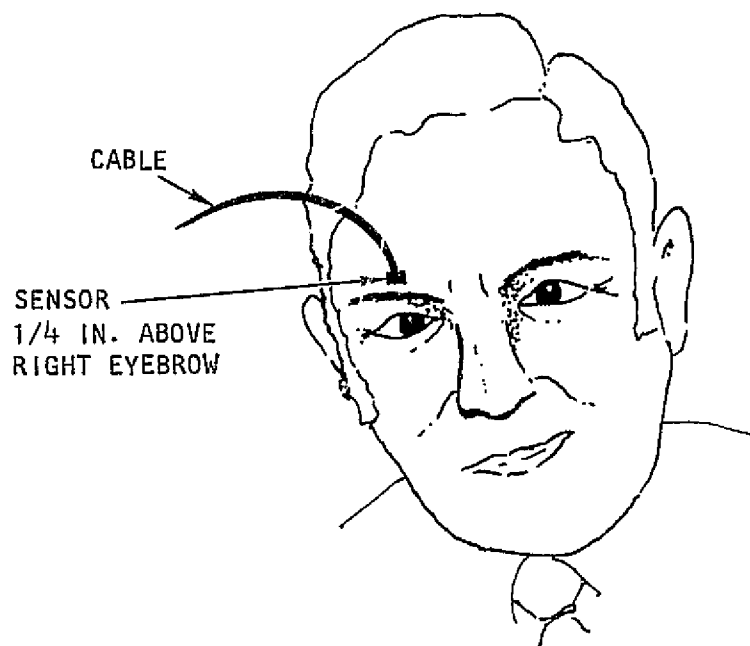
S-89022

Figure A-5.   Sensor Placement (FPG and HPG)

STEP 4

     Place stereo headphones on subject. Be sure that the level controls located on each headphone are on full.

STEP 5

     Turn on the BK and balance the unit using the procedure outlined below:

    a.   Turn master switch to BATT TEST position. Note that the meter reads in the green area.

    b.   Turn the master switch to AC SHORT position

    c.   Turn BALANCE control until meter reads in the green area of the scale.

    d.   Turn GAIN control fully clockwise.

STEP 6

     Set the trigger level controls (located on the front of the PA conditioner unit) so that the LED indicators, located under each level control, flash at a constant rate. A constant flashing rate indicates that the trigger circuit is set to the proper level for consistent data output.

     Turning the level control clockwise from midtravel gives an increasing positive trigger level, turning counterclockwise from midtravel gives an increasing negative level.

STEP 7

     Set the audio simulator frequency control, located on the right side of the PA conditioner front panel, to the frequency of 1656 Hz.

     The PA signal conditioning system is ready for use at this time.

METHOD OF CALIBRATION

     The PA signal conditioner has only one circuit that requires calibration, this is the audio response simulator. For this circuit, the audio sound level should be calibrated for a range of 60 to 110 db. To aid in this calibration, a B&K artificial ear, model 4153, has been purchased as part of the PA system hardware.

     The equipment needed for calibration is as follows:

       Dc power supply (+5 v at 100 ma)

       Artificial ear (B&K model 4153)

Headphones (part of PA unit)

1/2-in. microphone cartridge (B&K model 4134)

Cathode follower (B&K model 2615)

Sound level meter (B&K model 2203)

Octave filter set (B&K model 1613)

To calibrate the audio response system, the following procedures apply:

STEP 1

a. Plug PA signal conditioner into a 115-v, 60-Hz power line.

b. Turn on power and allow a 5-min warmup period.

c. Plug stereo headphones into PA signal conditioner audio output jack (located on front panel)

d. Make sure both level controls on headphones are on full.

e. Set up the B&K equipment per the instruction manual BB4153.

STEP 2

Short the following pins on the computer input connector together (connector located on lower right of PA front panel): pins F, P, C, D, R, V, U, K.

STEP 3

Apply 5 vdc on pins F (neg) and J (pos).

STEP 4

Adjust trimpot R8, located on the rear edge of card 9 (green ejector code), so that a level of +40 db is indicated on the B&K sound-level meter. The frequency control should be set at midtravel for this step.

STEP 5

Short the following pins on the computer input connector together and then connect this bus to the 5-vdc positive supply line: pins P, C, D, R, V, U, K.

STEP 6

The sound should be adjusted at this time to +110 db using trimpot R8 on card 9. This sets the full-scale sound level. Following this adjustment, the lower limit can be checked using step 2 to determine the total range of the audio response simulator (which should be about 45 db).

The unit is calibrated for use following step 6.

A-20

# APPENDIX B

# SYSTEM SCHEMATICS

FOLDOUT FRAME 1

POWER S1   1 AMP F1

117 VAC 60~

AC/DC ±15V PS1

+S +15   COM   -15 -S

SENSOR EEG   D

PTO2A-8-4S   A B C D

+15V   COM   -15V

TIE   LOSS

PEG   FPG   P4
PTO2A-8-6S   PTO2A   PTO2A-B-SS
A B C   A B C L   A B C

24V 5A

RED   DIALCO MDA94A7   24V   +57

T1   DIALCO 24V

REG LEVEL   10K 10T P3   CW

PG LEVEL   10K 10T R2   CW

EPG LEVEL   10K 10T R1   CW

L1   L2   L3   D

EEG CARD
LSK 36171
SLOT 1
RED EJECTOR

EPG CARD
LSK 36173
SLOT 3
YELLOW EJECTOR

PG CARD
LSK 36172
SLOT 2
ORANGE EJECTOR

REG CARD
LSK 36175
SLOT 0
VIOLET EJECTOR

P3 PEDAL &
POWER SUPPLY
LSK 36174
SLOT 4
YELLOW EJECTOR

PG
COM
LS

| | REVISIONS | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVED |
| A | ADDED ... | JAN 73 | |

COMPUTER
PT009-14-195

P C D R V U K T S E J F G H A B

R5
100K
QUAL
FREQ POT
CWI R5

T2

EEG
LEVEL 10K
10T
R7

| PS-EEG-REG COMPARATER LSK 36176 | EPG CHANGE LSK 36177 | PG CHANGE LSK 36178 | AUDIO LEVEL CONTROL LSK 36179 | AUDIO DRIVER LSK 36180 |
|---|---|---|---|---|
| SLOT 6 VIOLET EJECTOR | SLOT 7 VIOLET EJECTOR | SLOT 8 VIOLET EJECTOR | SLOT 9 GREEN EJECTOR | SLOT 10 GREEN EJECTOR |

LSK 36170

| | | | | PART OR | | |
|---|---|---|---|---|---|---|
| | | R5 | | | POT DUAL AB TYPE CCJ-104 | |
| | | R1-R4 | | | LISTED ON LSK 36172, LSK36173, LSK36175, LSK36176 | |
| | | L1-L4 | | | LED DIALCO 521-9165 | |
| | | PS1 | | | AC/DC MODEL QA15D1.1-1 | |
| | | T2 | | | AUDIO TRANS - STANCOR TA-42 | |
| | | T1 | | | 24V @ 1.0A - TRORASON 21F101 | |
| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | | NOMENCLATURE OR DESCRIPTION | SYM |
| | ← ASSY | | | | PARTS LIST | |

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC553

IDENTIFICATION MARKING PER MC16

STD INTERPRETATIONS PER 7M85

| HEAT TREATMENT | PROCESS |
|---|---|
| HARDNESS AND SPEC | NAME AND SPEC |

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
LOS ANGELES, CALIFORNIA

S.C. SYSTEM WIRING,
PSYCHOLOGICAL
ASSESSMENT

| SIZE | CODE IDENT NO. | DWG NO. |
|---|---|---|
| D | 70210 | LSK 36170 |
| SCALE ~ | | SHEET 1 OF 1 |

| REQD | NEXT ASSY | USED ON |
|---|---|---|
| | APPLICATION | |

ORIGINAL PAGE IS
OF POOR QUALITY

## REVISIONS

| LTR | DESCRIPTION | DATE | APPROVED |
|-----|-------------|------|----------|
|     |             |      |          |

FOLDOUT FRAME 2



LSK36171

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SYM |
|----------|----------|----------------|-------------------------|------------------------------|-----|
|  |  |  | Z2 | OP AMP UA741 | |
|  |  |  | Z1 | OP AMP U7A7747312 | |
|  |  |  | D1, D2 | DIODE 1N914 | |
|  |  |  | C5, C6 | CAPACITOR .01 uf | |
|  |  |  | C3, C4 | CAPACITOR 100 uf - 6VDC | |
|  |  |  | C1, C2 | CAPACITOR .015 uf | |
|  |  |  | R11, R12 | POTENTIOMETER 10K | |
|  |  |  | R10 | RESISTOR 100K 2% | |
|  |  |  | R8, R9 | 100K .1% | |
|  |  |  | R6, R7 | 10K .1% | |
|  |  |  | R4, R5 | 100K .1% | |
|  |  |  | R3 | 2K .1% | |
|  |  |  | R1, R2 | RESISTOR 10K 5% | |

⟵ ASSY   PARTS LIST

| HEAT TREATMENT | PROCESS |
|----------------|---------|
| HARDNESS AND SPEC | NAME AND SPEC |

CONTRACT NO.

DFT
CHK
VALUE ENGR
MATL
STRESS
APPD
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
LOS ANGELES, CALIFORNIA

# SCHEMATIC, ECG AMPLIFIER – PSYCHOLOGICAL ASSESSMENT

| SIZE | CODE IDENT NO. | DWG NO. |
|------|----------------|---------|
| C | 70210 | LSK36171 |

SCALE NONE   SHEET 1 OF 1

USED ON

B-2

TP

PG ANALOG OUT — C

820pf C7

1MΩ 5% R4

R1 50K

— D

+ E

50K R2

1/2 Z1

820pf C4

1M 5% R5

68µf 15V C1 C2

20K R6

10K R8

G91N R3 50K CW

1/2 Z1

1K R7

10K R9

CR1 CR2

300pf C3

-15V +15

22M R17

Z2

PG LEVEL

10K 10T R23

< K

10K R10

PG OUT M (PULSE)

< F

24K R15 → -15V

< J

24K R16 → +15V

+15V

C5 15µf

10K R12

6.8K R18

342    Z3

5.1K R19

15µf C6

CR4

COM R,S,14,15

10K R11

CR3 1N914

TP

FROM EPG PULSE OUTPUT L

5.1K R20

680Ω R21

Q2 2N3904

PG { LED-10

EPG { LED+

LED-3

680Ω R22

Q1 2N3904

+15V  N,P,12,13 → +15V

9  13  7

A1   A2

-15V  A,B,1,2 → -15V

4    4

ORANGE EJECTOR SLOT 2

+15V -15V

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. |
|---|---|---|---|
| | | | ← ASSY |

| | |
|---|---|
| CR1-CR4 | |
| Z3 | |
| Z2 | |
| Z1 | |
| Q1-Q2 | |
| C5-C6 | |
| C4,C7 | |
| C3 | |
| C1-C2 | |
| R23 | |
| R21-R22 | |
| R19-R20 | |
| R18 | |
| R17 | |
| R15-R16 | |
| R14 | |
| R13 | |
| R8-R12 | |
| R7 | |
| R6 | |
| R4-R5 | |
| R3 | |
| R1-R2 | |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 — .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC653
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL PER MIL-STD-8

DFT
CHK
VALUE ENGR
MATL
STRESS
APPD
APPD
AIRESEARCH APPD

HEAT TREATMENT | PROCESS
HARDNESS AND SPEC | NAME AND SPEC

OTHER ACTIVITY APPD

| REQD | NEXT ASSY | USED ON |
|---|---|---|
| | APPLICATION | |

| LTR | REVISIONS | | |
|-----|-----------|------|----------|
| | DESCRIPTION | DATE | APPROVED |
| | | | |

FOLDOUT FRAME 2

GAIN
R3 50K
R28
10K
CW

-15V  +15V

22M
R17

10K
R9

Z1
10

Z2
3 4
2 7 6
8
1

CR1  CR2

200Ω
R14

TP

1.5K
R13

300pf
C3

10K
R10

C5
15uf

Z3

5.1K
R19

CR4

CR3
1N914

TP

| | | | |
|---|---|---|---|
| CR1 - CR4 | DIODE 914 | | |
| Z3 | O/S, DUAL TELEDYNE 342CJ | | |
| Z2 | IC OP-AMP FAIRCHILD UA7709312 | | |
| Z1 | IC OP-AMP FAIRCHILD U7A7747312 | | |
| Q1 - Q2 | TRANSISTOR 2N3904 | | |
| C5 - C6 | CAPACITOR 15 uf 100 V | | |
| C4, C7 | 820pf 100V | | |
| C3 | 300pf 100 V | | |
| C1 - C2 | CAPACITOR 68 uf 15V | | |
| R23 | POT BOURNS 10 T-10K 35005-2-103 | | |
| R21 - R22 | RESISTOR 680Ω 1/2 W 5% | | |
| R19 - R20 | 5.1K 1/4 W 2% | | |
| R18 | 6.8K | | |
| R17 | 22M | | |
| R15 - R16 | 24K | | |
| R14 | 200Ω | | |
| R13 | 1.5K | | |
| R8 - R12 | 10K | | |
| R7 | 1K | | |
| R6 | 20K 2% | | |
| R4 - R5 | RESISTOR 1M 1/4 W 5% | | |
| R3 | TRIM POT BOURNS 50K | | |
| R1 - R2 | RESISTOR 50K 1/4 W 2% | | |

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SYM |
|----------|----------|----------------|-------------------------|-----------------------------|-----|
| ← ASSY | | | | PARTS LIST | |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 — .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC653
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL PER MIL-STD-8

CONTRACT NO.
DFT  Dan Lee  19 SEPT 72
CHK
VALUE ENGR
MAT'L
STRESS
APPD  9/22/72
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

HEAT TREATMENT  PROCESS
HARDNESS AND SPEC  NAME AND SPEC

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
LOS ANGELES, CALIFORNIA

PLETHYSMOGRAPH AMPLIFIER, PSYCHOLOGICAL ASSESSMENT

| SIZE | CODE IDENT NO. | DWG NO. | |
|------|----------------|---------|--|
| C | 70210 | LSK 36172 | |
| SCALE ~ | | SHEET 1 OF 1 | |

LSK 36172

REV LETTER

USED ON

B-3

TP

EPG OUT M
(PULSE

200 Ω
R15

C1
820 pf

R3
1M
5%

R1
50K
INPUT
— D

50K
+ E
R2

Z1
½ A1
1
2
13
9
12
4

+15V −15V

1M
5%
R4

+15V

68 μf
15V
C2 C3

20K
R5

10K
R6

R16 GAIN ①
50K
CW

Z1
½ A1
7
6
10

6.8K
R9

EPG ANALOG OUT C

820 pf
C4

R12
1K

R,S

22M
5%
R10

−15V +15V

10K
R7
CR1

CR2
Z2

A2
3
2
4
7
1
6
8

300 pf
C5

1.5K
R11

TP

PG LEVEL
10K
10T
R17

F
24K
R13
−15V

K
10K
R8

J
24K
R14
+15V

+15V N,P
+15V

9 13 7
A1  A2
4   4

−15V A,B
−15V

YELLOW EJECTOR
SLOT 3

| | | | PART OR IDENTIFYING NO. |
|---|---|---|---|
| | | | CR1–CR2 |
| | | | C5 |
| | | | C2–C3 |
| | | | C1,C4 |
| | | | Z2 |
| | | | Z1 |
| | | | R17 |
| | | | R16 |
| | | | R15 |
| | | | R13–R14 |
| | | | R12 |
| | | | R11 |
| | | | R10 |
| | | | R9 |
| | | | R6–R8 |
| | | | R5 |
| | | | R3–R4 |
| | | | R1–R2 |

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. |
|---|---|---|---|
| | ← ASSY | | |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 — .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC653
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL. PER MIL-STD-8

DFT
CHK
VALUE ENGR
MATL

HEAT TREATMENT PROCESS
HARDNESS AND SPEC  NAME AND SPEC

STRESS
APPD
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

| REQD | NEXT ASSY | USED ON |
|---|---|---|
| | APPLICATION | |

FOLDOUT FRAME 2



**Parts List**

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SYM |
|----------|----------|----------------|-------------------------|-----------------------------|-----|
|  |  |  | CR1-CR2 | DIODE 1N914 |  |
|  |  |  | C5 | CAPACITOR 300pf |  |
|  |  |  | C2-C3 | 68 uf - 15V |  |
|  |  |  | C1, C4 | CAPACITOR 820 pf |  |
|  |  |  | Z2 | IC OP AMP FAIRCHILD UA709 |  |
|  |  |  | Z1 | IC OP AMP FAIRCHILD U7A7747312 |  |
|  |  |  | R17 | POT BOURNS 10K 10T 3500S-2-103 |  |
|  |  |  | R16 | TRIM POT BOURNS 50K |  |
|  |  |  | R15 | RESISTOR 200Ω 1/4 WATT 5% |  |
|  |  |  | R13-R14 | 24K 2% |  |
|  |  |  | R12 | 1K 2% |  |
|  |  |  | R11 | 1.5K 2% |  |
|  |  |  | R10 | 22M 5% |  |
|  |  |  | R9 | 6.8K 2% |  |
|  |  |  | R6-R8 | 10K |  |
|  |  |  | R5 | 20K 2% |  |
|  |  |  | R3-R4 | 1M 5% |  |
|  |  |  | R1-R2 | RESISTOR 50K 1/4 WATT 2% |  |

← ASSY

PARTS LIST

CONTRACT NO.

DFT Dan Lee 20 SEPT 72
CHK
VALUE ENGR
MATL
STRESS
APPD   9/29/72
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
LOS ANGELES, CALIFORNIA

**PLETHYSMOGRAPH AMPLIFIER, PSYCHOLOGICAL ASSESSMENT**

| SIZE | CODE IDENT NO. | DWG NO. |
|------|----------------|---------|
| C | 70210 | LSK 36173 |

SCALE ~    SHEET 1 OF 1

LSK 36173
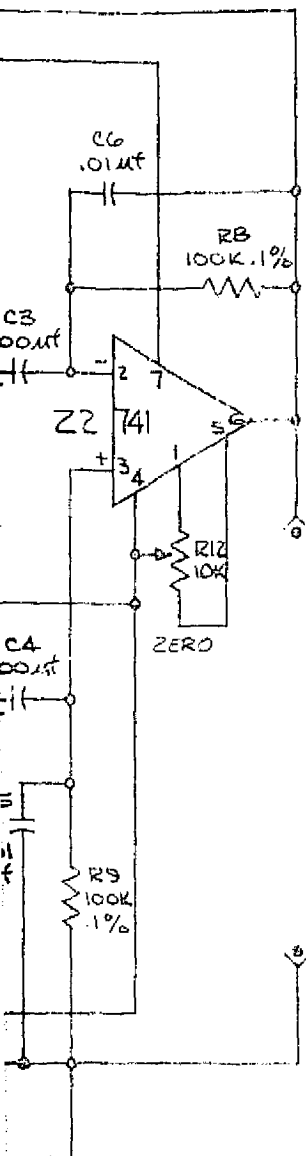
B-4

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CORPORATION.

$L_1$ + 4

+30V BRIDGE POWER   1,2

$L_2$ + 5

TP

R17

LM309H

Z2
2   1
3

R16
400Ω

PG + 11

R1
5.6k

PG OUT
+ 13
− 12

R5
10k

COM  7

TP

Z1

14 13 12 11 10 9 8
1 2 3 4 5 6 7

EPG OUT
+ 8
− 10

R6
10K

R8
4.7K

+ 1µf
C1

1µf
C2 +

R12
2.1k

6.2
K
R14

1000µf
C3

10K
R4

10K
R7

4.7K
R9

470
R15

5.6K
R3

300Ω
R13

BRIDGE POWER − 14,15

R2
5.6K

8.2K
R10

15K
R11

EPG + 9

TP

YELLOW EJECTOR
SLOT 4

| | | | |
|---|---|---|---|
| | | Z2 | |
| | | Z1 | |
| | | C3 | |
| | | C1-C2 | |
| | | R17 | |
| | | R16 | |
| | | R15 | |
| | | R14 | |
| | | R13 | |
| | | R12 | |
| | | R11 | |
| | | R10 | |
| | | R8-R9 | |
| | | R4-R7 | |
| | | R1-R3 | |

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. |
|---|---|---|---|
| | | ←— ASSY | |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 — .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC651
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL. PER MIL-STD-8

DFT
CHK
VALUE ENGR
MATL
STRESS
APPD
APPD
AIRESEARCH APPD
OTHER ACTIVITY APP

HEAT TREATMENT   PROCESS
HARDNESS AND SPEC   NAME AND SPEC

REQD   NEXT ASSY   USED ON
APPLICATION

| REVISIONS | | | | |
|---|---|---|---|---|
| LTR | DESCRIPTION | | DATE | APPROVED |

FOLDOUT FRAME 2



Z1

6.2 K R14

1000 pf C3

300 Ω R13

15K R11

TP

LSK 36174

REV LETTER

| | PARTS LIST | | | |
|---|---|---|---|---|
| Z2 | REGULATOR NATIONAL LM304H | | | |
| Z1 | REGULATOR FAIRCHILD µA723 | | | |
| C3 | CAPACITOR 1000pf | | | |
| C1-C2 | CAPACITOR 1µf 35VDC | | | |
| R17 | RESISTOR SELECTED 3 WATT | | | |
| R16 | | 400 Ω | 3 WATT 2% | |
| R15 | | 470 Ω | 3 WATT 2% | |
| R14 | | 6.2K | 1/4 WATT | |
| R13 | | 300 Ω | | |
| R12 | | 2.7K | | |
| R11 | | 15K | | |
| R10 | | 8.2K | | |
| R8-R9 | | 4.7K | | |
| R4-R7 | | 10K | | |
| R1-R3 | RESISTOR 5.6K Ω 1/4 WATT 2% | | | |

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SYM |
|---|---|---|---|---|---|
| | | | | PARTS LIST | |

← ASSY

| HEAT TREATMENT | PROCESS |
|---|---|
| HARDNESS AND SPEC | NAME AND SPEC |

CONTRACT NO.

DFT   20 SEPT 72
CHK
VALUE ENGR
MATL
STRESS
APPD
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

GARRETT · AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
LOS ANGELES, CALIFORNIA

PG POWER SUPPLY & BRIDGE, PSYCHOLOGICAL ASSESSMENT

| SIZE | CODE IDENT NO. | DWG NO. | | |
|---|---|---|---|---|
| C | 70210 | LSK 36174 | | |
| SCALE ~ | | | SHEET 1 OF 1 | |

B-5

TP

PULSE OUTPUT M

ANALOG OUTPUT C

R9 1K

R6 10K

R13 5% 22M

R1 10K

INPUT

D

E

R2 10K

−15V +15V

2 4 7 6

Z1

5

1

R12 5% 10K

1N914 CR2

CR3

−15V +15V

4

3

2

Z2

7 6

1

8

200Ω R10

10K 10T R15

−15V

300pf C1

5.1K

R8 68K

REG LEVEL

F

10K 10T R16

K

J

R3 10K

68K R7

+15V

1.5K R11

10K R4

½ WTT 680Ω R14

2N3904

LED − L

10K R5

Z3

16 15 14 13 12 11 10 9

1 2 3 4 5 6 7 8

+ C2 CR1

Q1

COM R,S

15 µf 15V

1N914

TP

N,P

+15V

7 7

Z1 Z2

4 4

A,B

−15V

VIOLET EJECTOR

SLOT 5

| | | | | | |
|---|---|---|---|---|---|
| | | | | | Z3 |
| | | | | | Z2 |
| | | | | | Z1 |
| | | | | | CR1−CR3 |
| | | | | | C2 |
| | | | | | C1 |
| | | | | | Q1 |
| | | | | | R15−R16 |
| | | | | | R14 |
| | | | | | R13 |
| | | | | | R12 |
| | | | | | R11 |
| | | | | | R10 |
| | | | | | R9 |
| | | | | | R7−R8 |
| | | | | | R1−R6 |

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. |
|---|---|---|---|
| | | | ← ASSY |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 — .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC653
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL PER MIL-STD-8

DFT
CHK
VALUE ENGR
MATL
STRESS
APPD
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

| | HEAT TREATMENT | PROCESS |
|---|---|---|
| | HARDNESS AND SPEC | NAME AND SPEC |

| REQD | NEXT ASSY | USED ON |
|---|---|---|
| | APPLICATION | |

| REVISIONS | | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVED |
| | | | |

FOLDOUT FRAME 2

$200\,\Omega$ R10

5.1K

TP

REV LETTER

LSK 36175

DWG. NO.

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SYM |
|---|---|---|---|---|---|
| | | | Z3 | LOGIC TELEDYNE DUAL O/S — 342A | |
| | | | Z2 | IC OP AMP FAIRCHILD 709 | |
| | | | Z1 | IC OP AMP FAIRCHILD 741 | |
| | | | CR1 - CR3 | DIODE 1N914 | |
| | | | C2 | CAPACITOR 15 uf 15V | |
| | | | C1 | CAPACITOR 300 pf | |
| | | | Q1 | TRANSISTOR 2N3904 | |
| | | | R15 - R16 | POT BOURNS 10K 10T | |
| | | | R14 | RESISTOR 680 $\Omega$ ½ WATT 2% | |
| | | | R13 | 22M ¼ WATT 5% | |
| | | | R12 | 10K 5% | |
| | | | R11 | 1.5K 2% | |
| | | | R10 | 200 $\Omega$ | |
| | | | R9 | 1K | |
| | | | R7 - R8 | 68K | |
| | | | R1 - R6 | RESISTOR 10K ¼ WATT 2% | |

← ASSY PARTS LIST

| HEAT TREATMENT | PROCESS |
|---|---|
| HARDNESS AND SPEC | NAME AND SPEC |

CONTRACT NO.
DFT Gary Lee    CO2/UT 72
CHK
VALUE ENGR
MATL
STRESS
APPD
APPD
AIRESEARCH APPO
OTHER ACTIVITY APPD

GARRETT AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
LOS ANGELES, CALIFORNIA

REG. PREAMPLIFIER, PSYCHOLOGICAL ASSESSMENT

| SIZE | CODE IDENT NO. | DWG NO. | | |
|---|---|---|---|---|
| C | 70210 | LSK 36175 | | |
| SCALE ~ | | | SHEET 1 OF 1 | |

B-6

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OUTPUT TO AUDIO AMPLF.    N

−15V    +15V

D
E
5
TO COMPUTER I/O CARD
F
H
K
9

DATEL D/A DAC 198B

10    9
1
2
3
12
4
5
6
7
14
8    15
11

5.1K R1

R2 5.1K

8.2K R3

2

Z1 741

3    +    4

6
7

−15V +15V

R6 1K

2.4K R5

10K R4

RB 10K TRIM POT LEVEL CALIB.

R7 1K

−15V    +15V

V−    V+
X INPUT    Z

FM MODEL 550

e₀

Y INPUT    SJ
COM

TO OS OUTPUT    M

COM    14,15

−15V    1,2    −15V

+15V    12,13    +15V

PIN LAYOUT DAC 198 B

9
10
11    1
12    2
13    3
14    4
15    5

6
7
16    8

BOTTOM VIEW

PIN LAYOUT 550

SJ    V+
X BOL    COM
X INPUT    V−
Y INPUT    e₀
Y BAL    e₀ BCL
Z

BOTTOM VIEW

GREEN EJECTOR

SLOT 9

| | | | |
|---|---|---|---|
| | | | Z1 |
| | | | C1 |
| | | | RB |
| | | | R6-R7 |
| | | | R5 |
| | | | R4 |
| | | | R3 |
| | | | R1-R2 |

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. |
|---|---|---|---|
| | ← ASSY | | |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 − .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC653
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL PER MIL-STD-8

DFT
CHK
VALUE ENGR
MATL
STRESS
APPD
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

HEAT TREATMENT    PROCESS
HARDNESS AND SPEC    NAME AND SPEC

REQD    NEXT ASSY    USED ON
APPLICATION

| | REVISIONS | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVED |
| | | | |

FOLDOUT FRAME 2



−15V    +15V

R6
1K

FM
MODEL
550

X INPUT    V−    V+    Z
e₀
y INPUT    SJ
COM

R7
1K

.68 µf
C1

DWG NO. LSK 36179

REV LETTER

| | | | SYM |
|---|---|---|---|
| Z1 | OP-AMP µA741 | | |
| C1 | CAPACITOR .68 µf | | |
| R8 | TRIM POT BOURNS 10K | | |
| R6-R7 | RESISTOR 1K 1/4 WATT 2% | | |
| R5 | 2.4K | | |
| R4 | 10K | | |
| R3 | 8.2K | | |
| R1-R2 | RESISTOR 5.1K 1/4 WATT 2% | | |

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SYM |
|---|---|---|---|---|---|
| | | | ← ASSY | PARTS LIST | |

| HEAT TREATMENT | PROCESS |
|---|---|
| HARDNESS AND SPEC | NAME AND SPEC |

CONTRACT NO.

DFT  Dan Lu  22 SEPT 72
CHK
VALUE ENGR
MATL
STRESS
APPD  9/26/72
APPD
AIRESEARCH APPD
OTHER ACTIVITY APPD

GARRETT  AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
LOS ANGELES, CALIFORNIA

AUDIO RESPONSE SIMULATOR PSYCHOLOGICAL ASSESSMENT

| SIZE | CODE IDENT NO. | DWG NO. |
|---|---|---|
| C | 70210 | LSK 36179 |

SCALE ~    SHEET 1 OF 1

B-7

FOLDOUT FRAME 1

OSCILLATOR OUTPUT K

R1 24K    C1 1500pf

750Ω

FREQ ADJUST

100K R13    100K R14

Z1 741

24K R2    1500 pf C2    GE1869D

+15V  -15V

GAIN

R15 20K

R6 51K

Z4

Z2 776

AUDIO IN  9

R5 5.1K

Z3 741

100Ω R11

2K R3    2.7 M R4    2.4K R7    510K

AUDIO OUTPUT  N

150Ω 3 WATT R8

.012 µf C4

-15V  1,2

10 µf C5

3 WATT 150Ω R9

.012 µf C3

+15V  12,13

10 µf C6

AMP GATE IN  8

10K R10    2N5962 Q1

5.6K R12

COM  14,15

GREEN EJECTOR

SLOT 10

| | | | | |
|---|---|---|---|---|
| | | | Z4 | |
| | | | Z3 | |
| | | | Z2 | |
| | | | Z1 | |
| | | | Q1 | |
| | | | C5-C6 | |
| | | | C3-C4 | |
| | | | C1-C2 | |
| | | | R15 | |
| | | | R13-R14 | |
| | | | R12 | |
| | | | R11 | |
| | | | R10 | |
| | | | R8-R9 | |
| | | | R7 | |
| | | | R6 | |
| | | | R5 | |
| | | | R4 | |
| | | | R3 | |
| | | | R1-R2 | |
| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING N___ | |
| | | ← ASSY | | |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 — .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC653
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL. PER MIL-STD-8

DFT  Dan
CHK
VALUE ENGR
MATL
STRESS

HEAT TREATMENT    PROCESS
HARDNESS AND SPEC    NAME AND SPEC

APPD
APPD
AIRESEARCH APP___
OTHER ACTIVITY___

REQD  NEXT ASSY  USED ON
APPLICATION

| | REVISIONS | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVED |
| | | | |

FOLDOUT FRAME 2

REV
LETTER

DWG NO. LSK 36180

| QTY REQD | ITEM NO. | CODE IDENT NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SYM |
|---|---|---|---|---|---|
| | | | Z4 | NATIONAL BOOSTER N.4002C | |
| | | | Z3 | OP-AMP FAIRCHILD 741 | |
| | | | Z2 | OP-AMP FAIRCHILD 776 | |
| | | | Z1 | OP-AMP FAIRCHILD 741 | |
| | | | Q1 | TRANSISTOR 245962 | |
| | | | C5-C6 | CAPACITOR 10µf - 35V | |
| | | | C3-C4 | CAPACITOR .012µf - 100V | |
| | | | C1-C2 | CAPACITOR 1500pf - 100V | |
| | | | R15 | TRIM POT BOURNS 20K | |
| | | | R13-R14 | POT AB-DUAL 100K | |
| | | | R12 | RESISTOR 5.6K ¼ WATT | |
| | | | R11 | 100Ω ¼ WATT | |
| | | | R10 | 10K ¼ WATT | |
| | | | R8-R9 | 150Ω 3 WATT | |
| | | | R7 | 2.4K ¼ WATT 2% | |
| | | | R6 | 51K | |
| | | | R5 | 5.1K | |
| | | | R4 | 2.7M | |
| | | | R3 | 2K | |
| | | | R1-R2 | RESISTOR 24K ¼ WATT 2% | |
| | ← ASSY | | | PARTS LIST | |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES.
MACHINE FILLET RADII .015 — .030
SURFACE ROUGHNESS PER MIL-STD-10
BURR CONTROL PER SC653
DIMENSION LIMITS HELD AFTER PLATING
IDENT MARKING PER MC16
DIMENSIONING AND TOL PER MIL-STD-8

| HEAT TREATMENT | PROCESS |
|---|---|
| HARDNESS AND SPEC | NAME AND SPEC |

CONTRACT NO.

| DFT | Dan Lee | 22 SEPT 72 |
|---|---|---|
| CHK | | |
| VALUE ENGR | | |
| MATL | | |
| STRESS | | |
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DRIVER AUDIO
PSYCHOLOGICAL
ASSESSMENT

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*(Schematic diagram at left includes components labeled: Z4, 100Ω R11, .012µf C4, .012µf C3)*

APPENDIX C

BIBLIOGRAPHY

# APPENDIX C

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